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INDIAN JOURNAL OF POWER & RIVER VALLEY DEVELOPMENT

VOL. XI, NO. 5 MAY, 1961 RUPEES TWO

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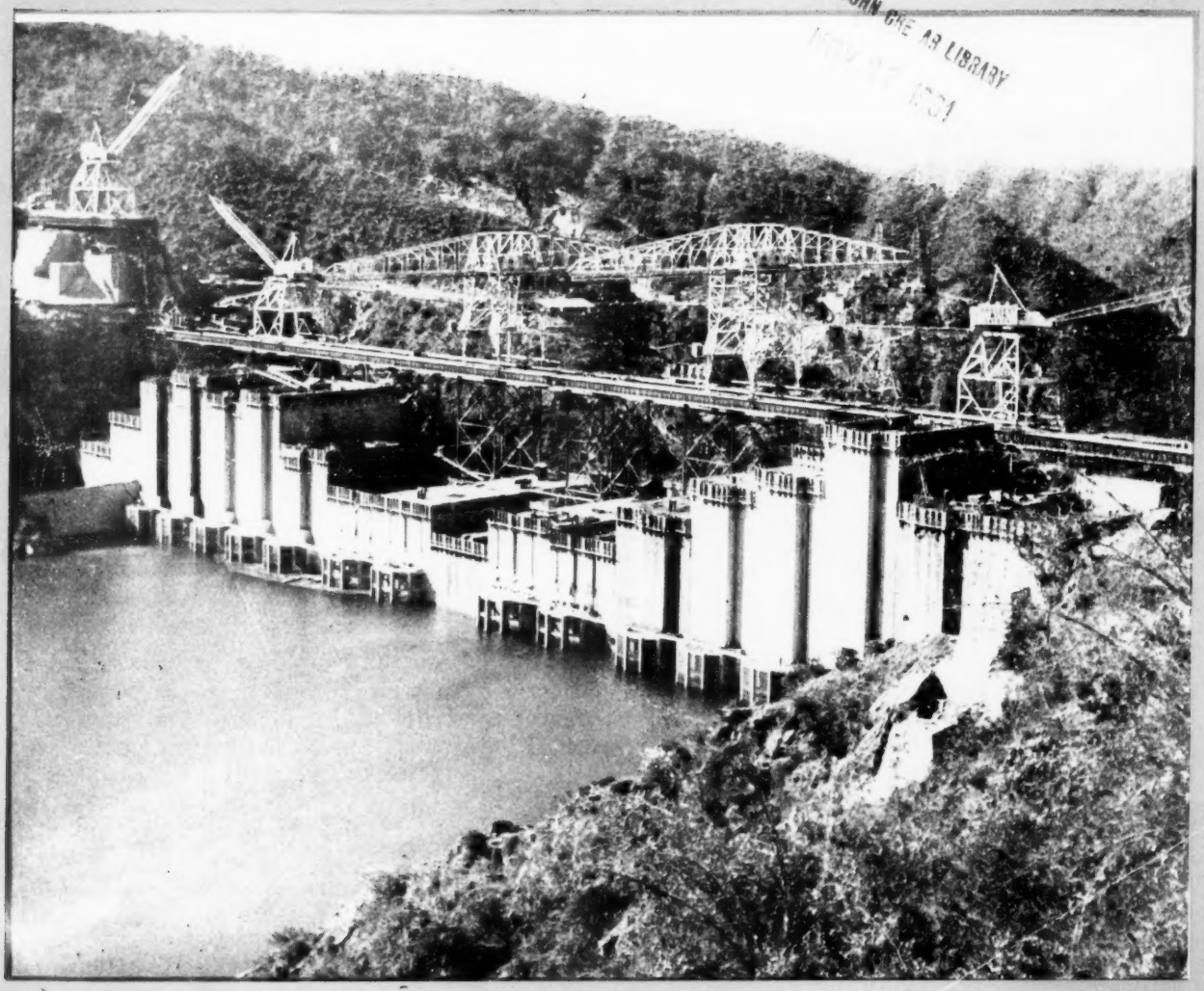

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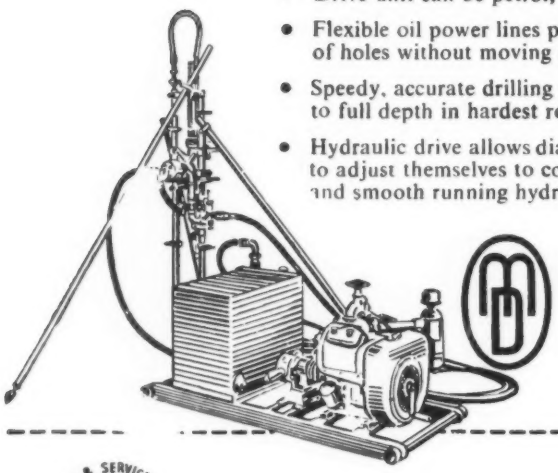

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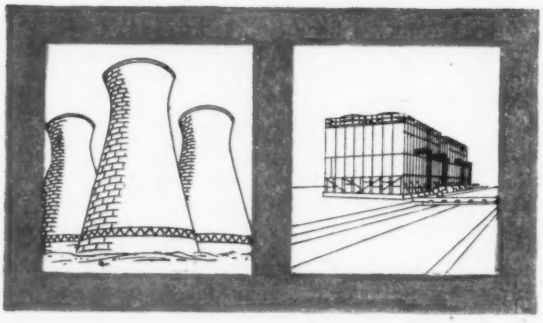

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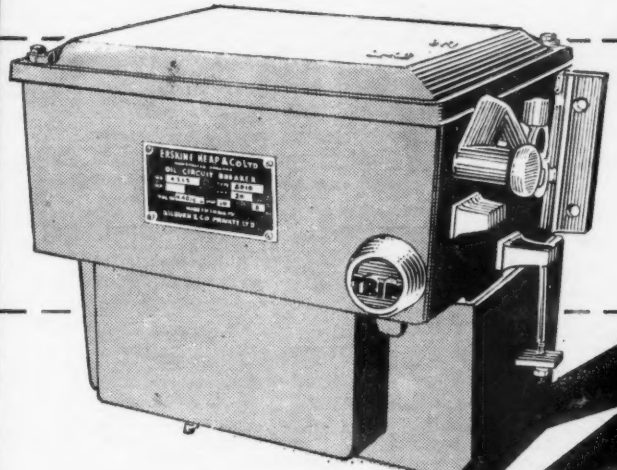

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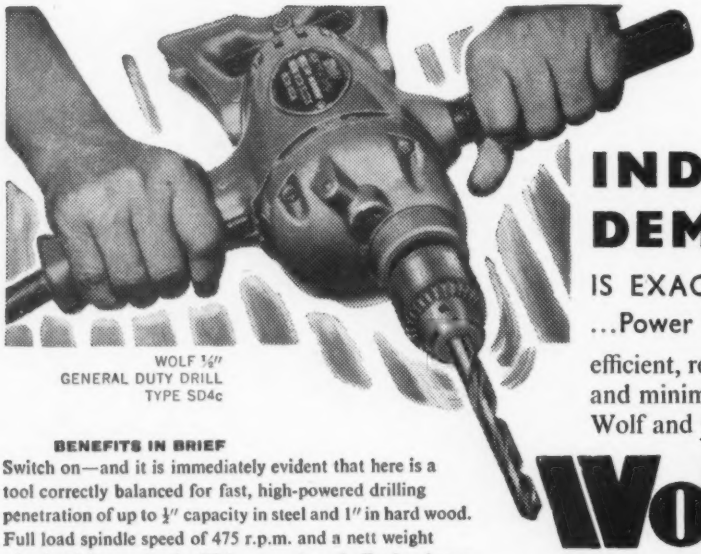

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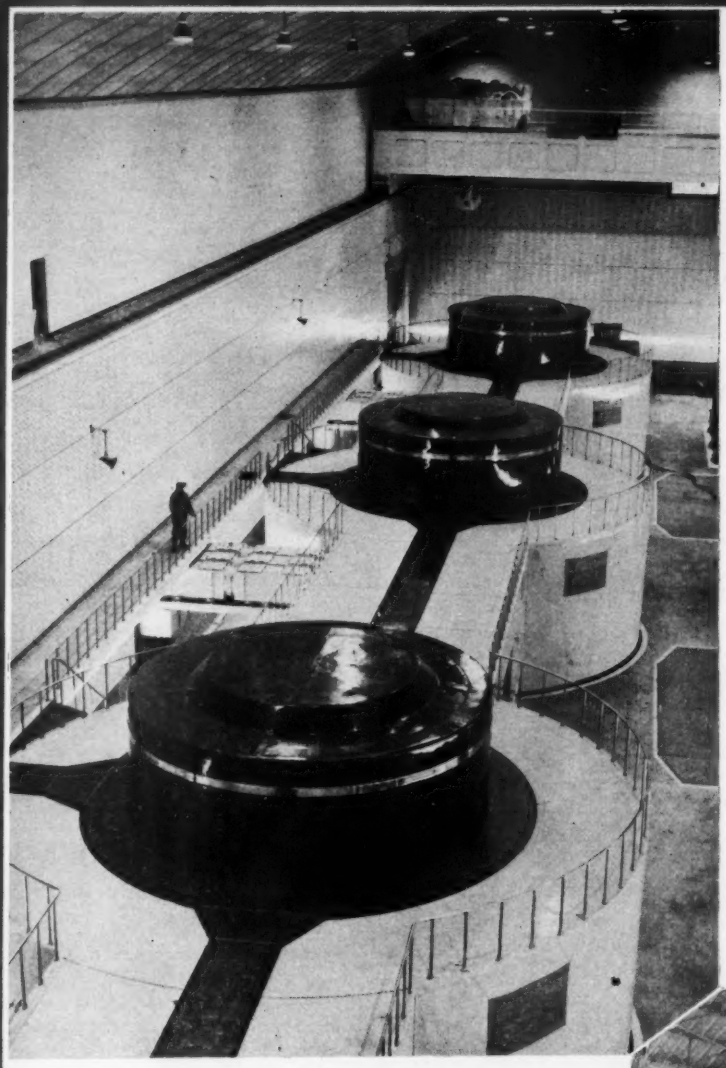

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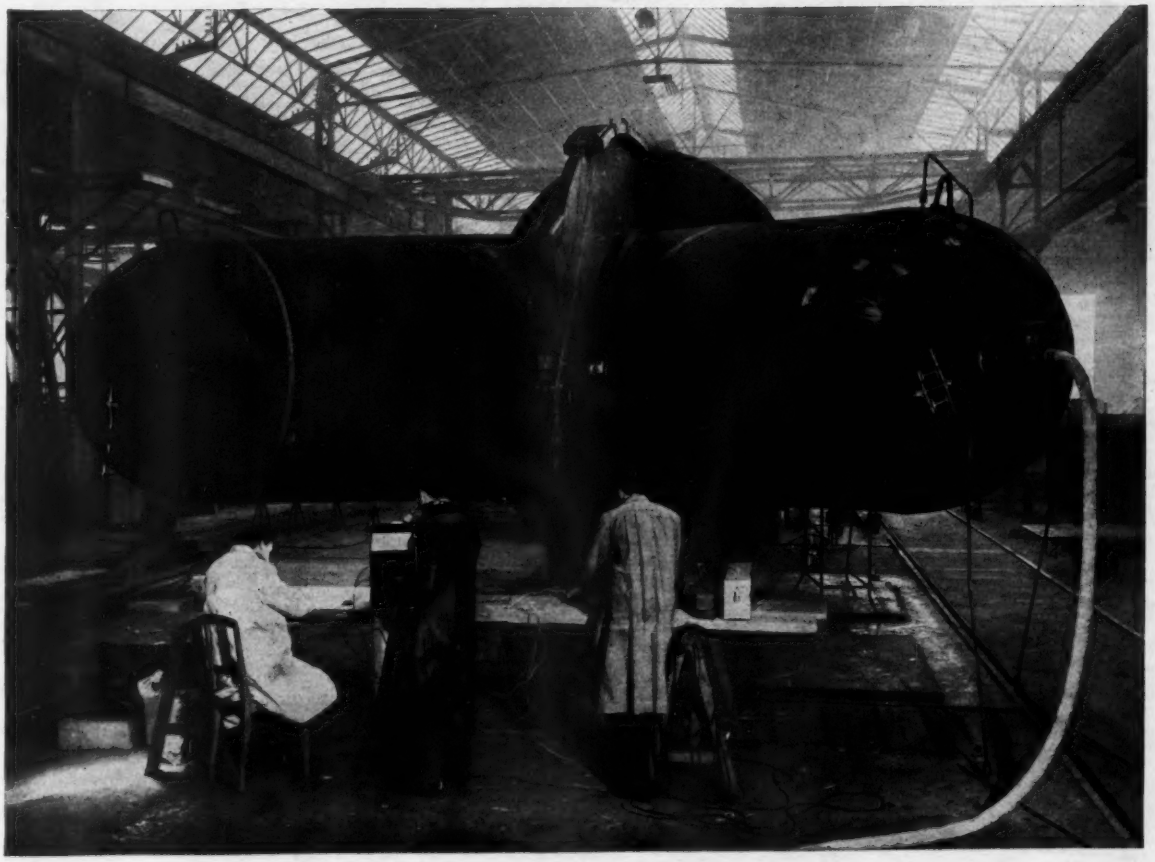

Pressure test and Electric Strain Measuring carried out on the manifold of the KOYNA POWER STATION (Maharashtra State). Test pressure 1420 psi. Diameters 8'6"/2×6'. Thickness 1" 27/32" and 1" 37/64. Weight 40.5 tons.

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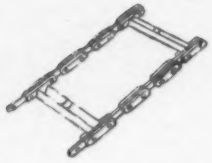
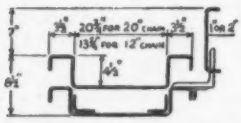
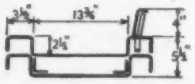


GENERAL DETAILS



STANDARD TYPE WITH OFFSET SPILLPLATE

METHOD OF APPLYING "ZEDD" LIDS



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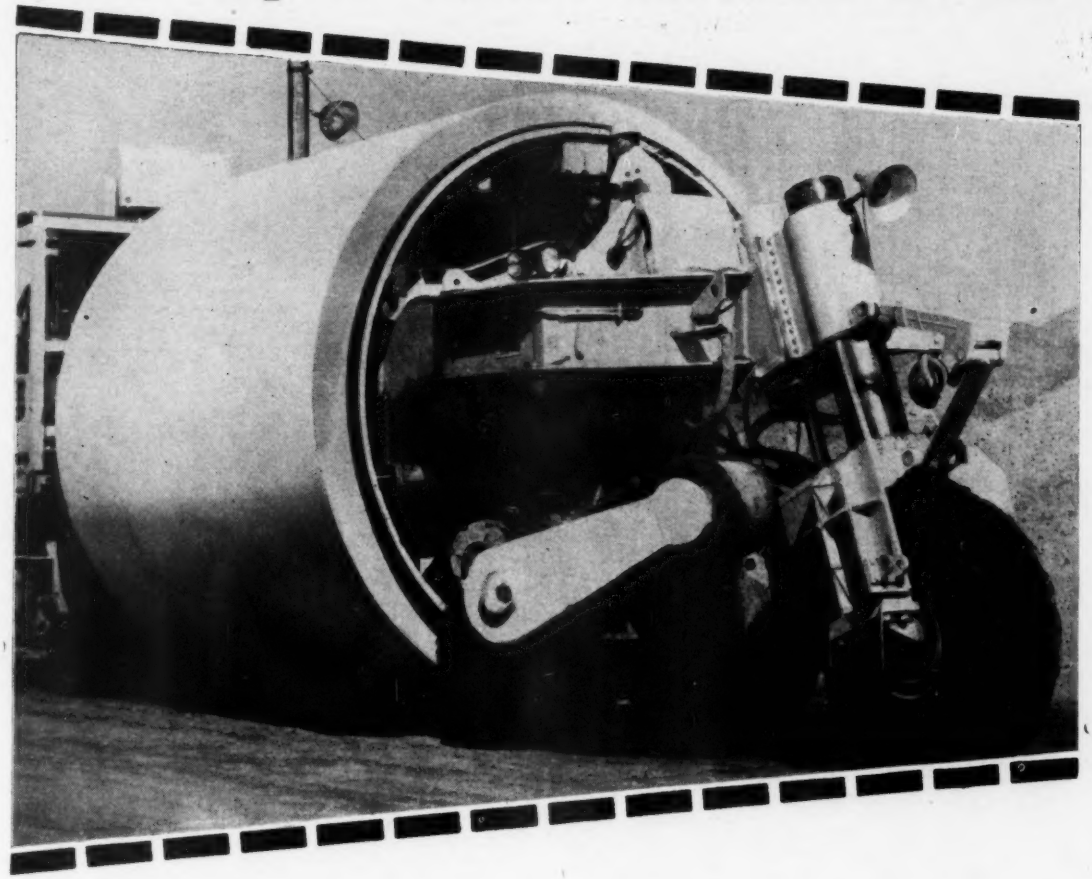

EACH WHEEL CARRIES 25 TONS ON TIMKEN TAPERED ROLLER BEARINGS

This unusual machine handles and installs 68-ton sections of precast concrete pipe. It rolls into the pipe with its front wheel elevated, then "walks" on to the wheel, does not crush the pipe edge. When it lifts the pipe each of the six wheels carries 25 tons. The wheel manufacturer, Kay-Brunner Steel Products, Inc., Los Angeles, Calif., U.S.A. wanted to be sure the machine would handle these tremendous loads. That's why they mounted two Timken tapered roller bearings in each wheel hub for rigidity and adjustability.

Because of their tapered design, Timken bearings take all radial and thrust loads. The full-line contact of Timken bearing races and rollers gives them extra load-carrying capacity.

Look for Timken bearings on the machines you buy. Specify Timken bearings for the machines you build. And let our engineers work with you to help you get the most for your bearing expenditure.' The Timken Roller Bearing Company, Canton, Ohio, U.S.A. Cable: "TIMROSCO".

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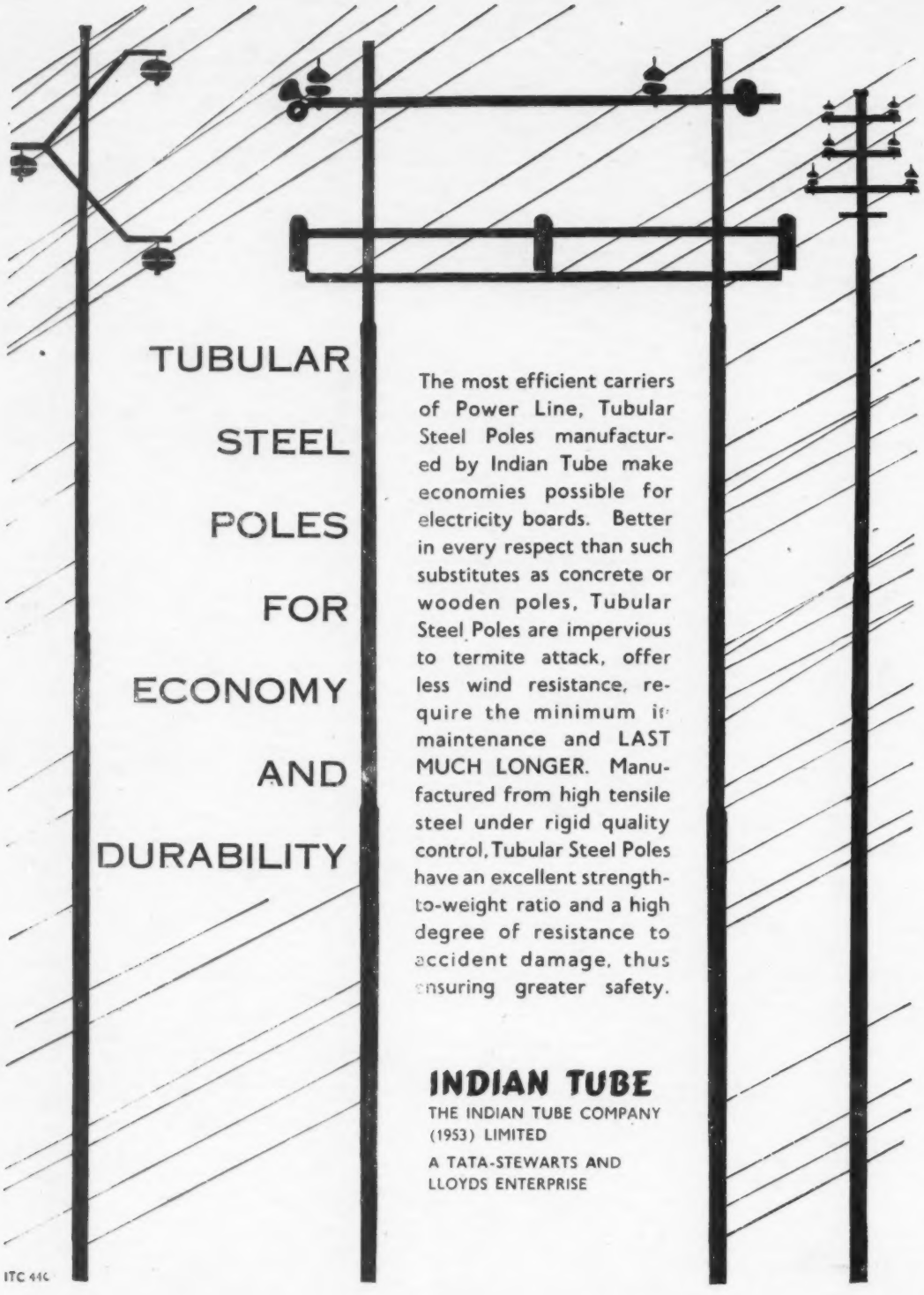

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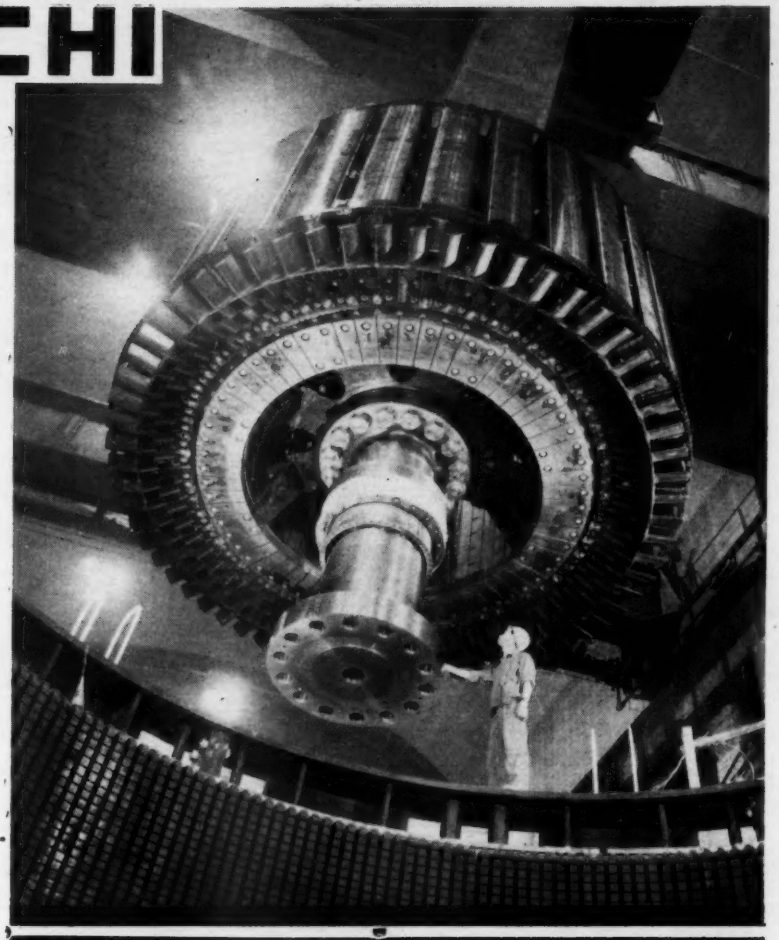

Hitachi has recently completed two 137,500 kw/125,000 kVA hydraulic turbines and generators for the Miboro Power Station in Central Japan. The turbine is of the vertical-shaft Francis type, and specified for a speed of 225 rpm, a maximum effective head of 200 m and 76.6 cu.m/sec water flow, making it one of the largest units of its kind in the world. Its runner has a maximum diameter of 3.7 m and the main shaft a diameter of 95 cm. The spiral casing, which was constructed in 13 sections to facilitate transportation to the site, has an inlet diameter of 3.35 m and an outer diameter of 11.2 m.

The generator presents a high-torsoed appearance, having been so designed in consideration of the comparatively high speed. Since the generator was designed for a rated voltage of 16,500 volts and, in this respect, represents the first such attempt in Japan, particular care was taken in the corona-shielding and impulse resistance of the stator winding. The generator is rated at 60 cycles, 225 rpm and 0.9 power factor but is also capable of operating at 50 cycles, 187.5 rpm and 1.0 power factor.

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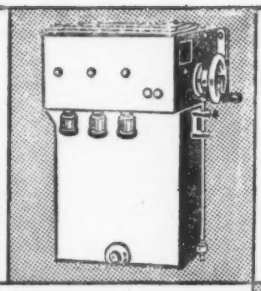
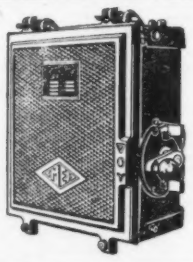
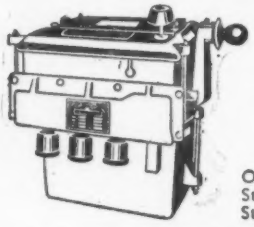


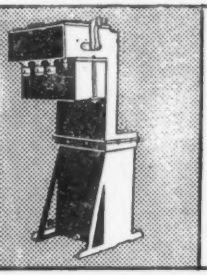
Oil Immersed Combined Rotor-Stator Starters



Air Break Star/Delta Starters

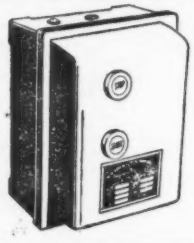


Oil immersed Star/Delta Starters



Auto Transformer Starters

Oil Immersed Push Button Direct-on-Line Starters



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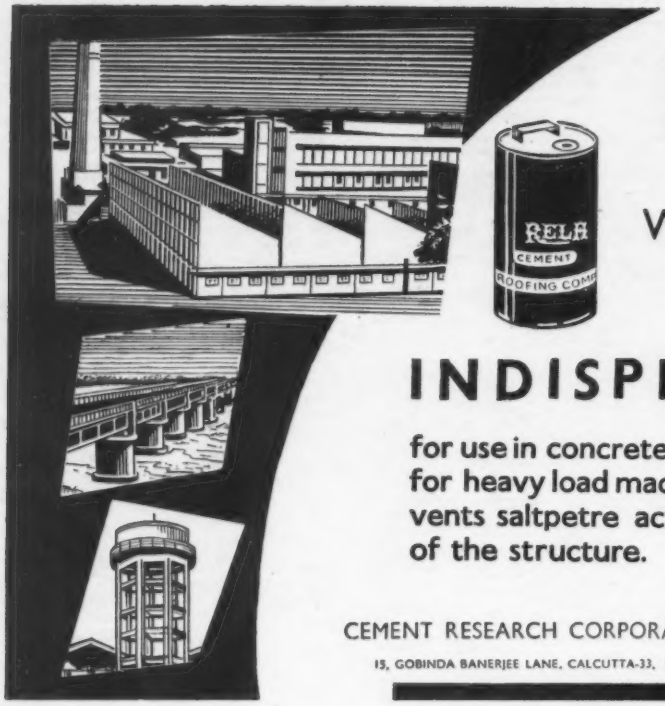

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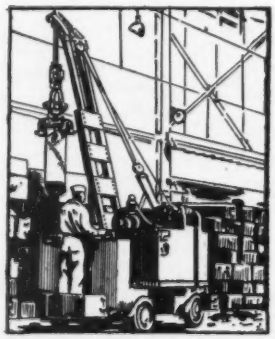
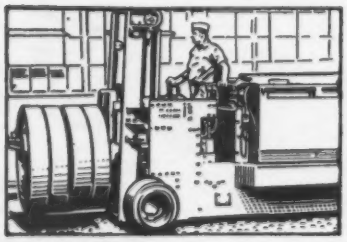
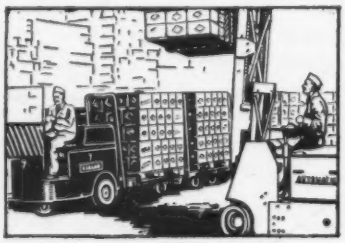


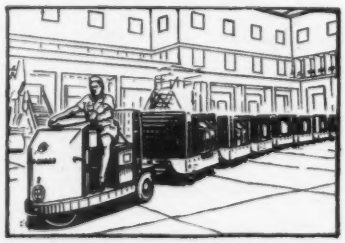
Crane Truck



Ram Truck



Fork-Lift Truck



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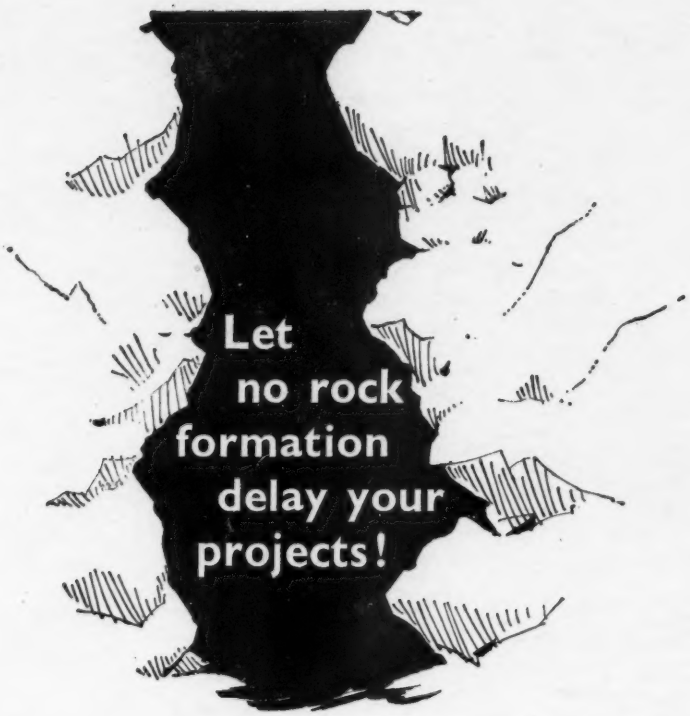

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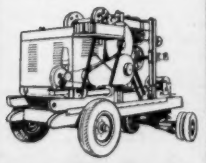

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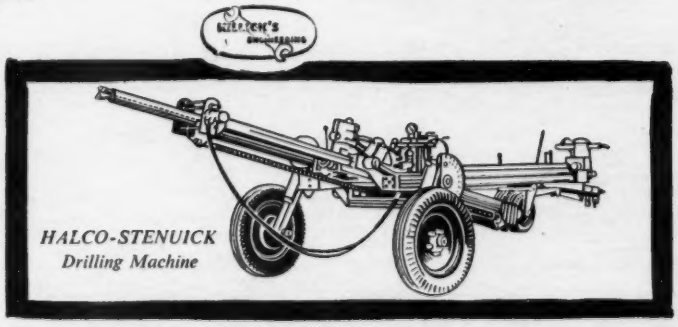

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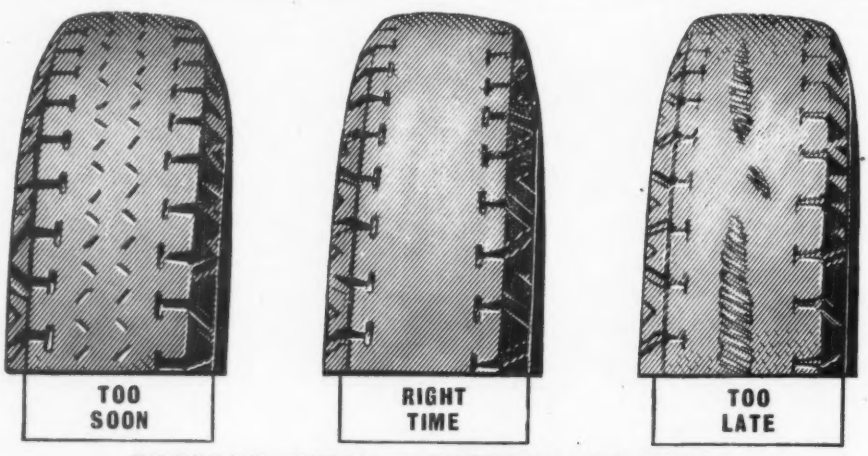

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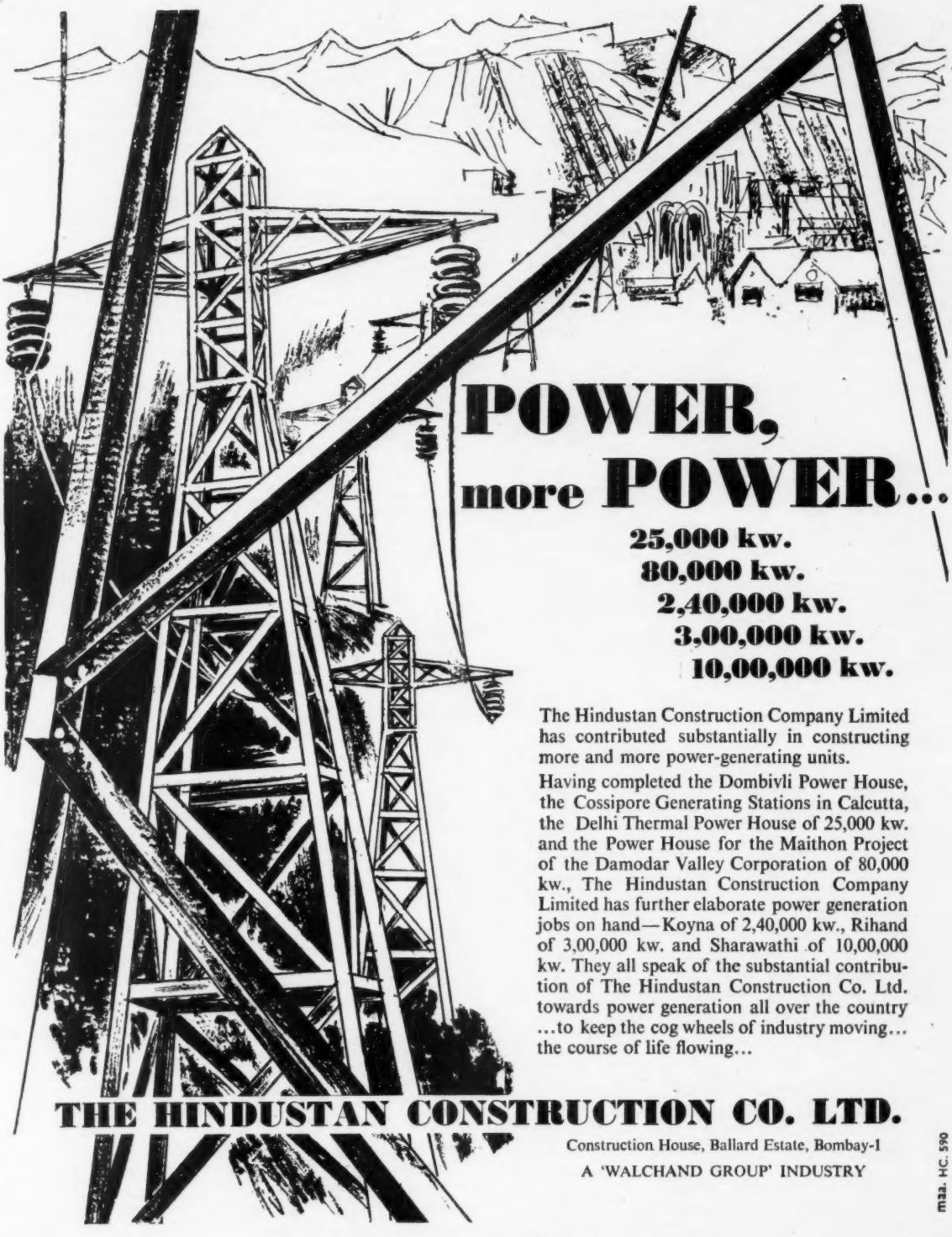

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STATESMAN
April, 3rd. 1961

Second Plan Coal Target Exceeded

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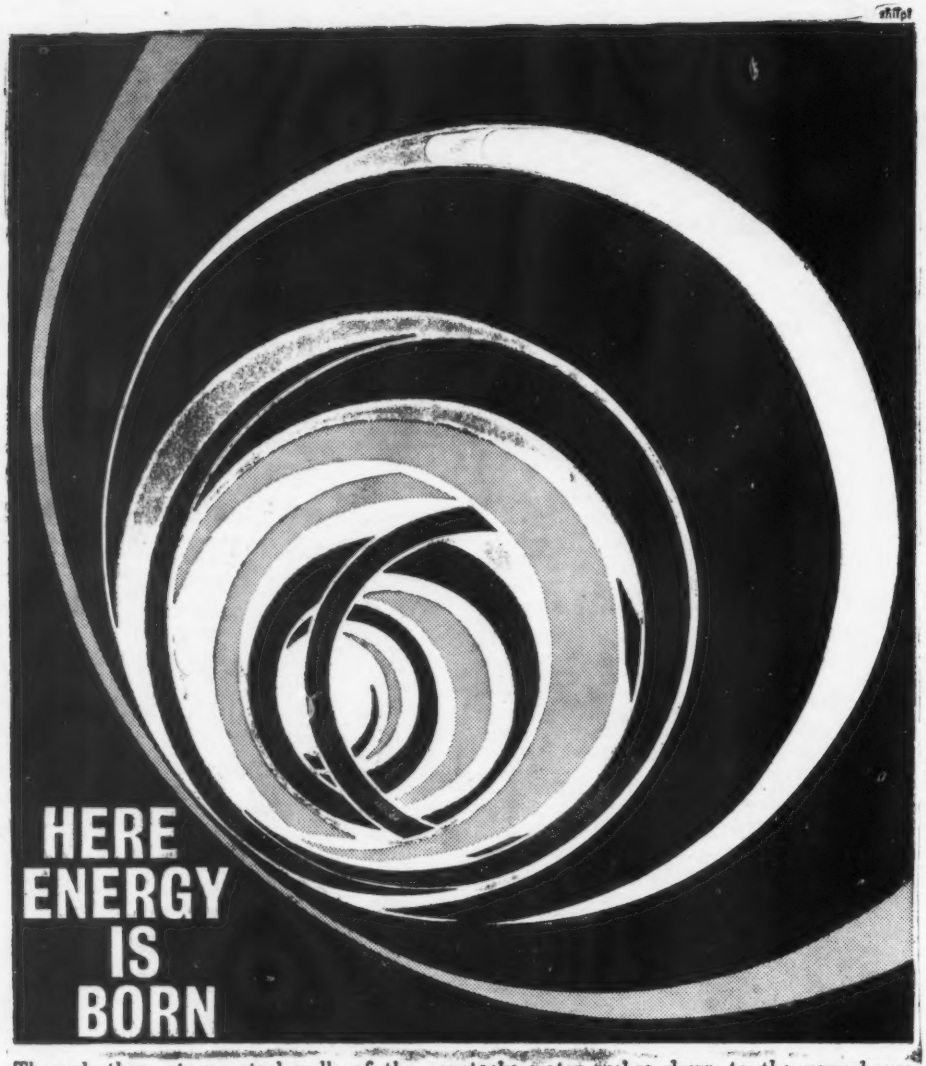

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MAY 1961

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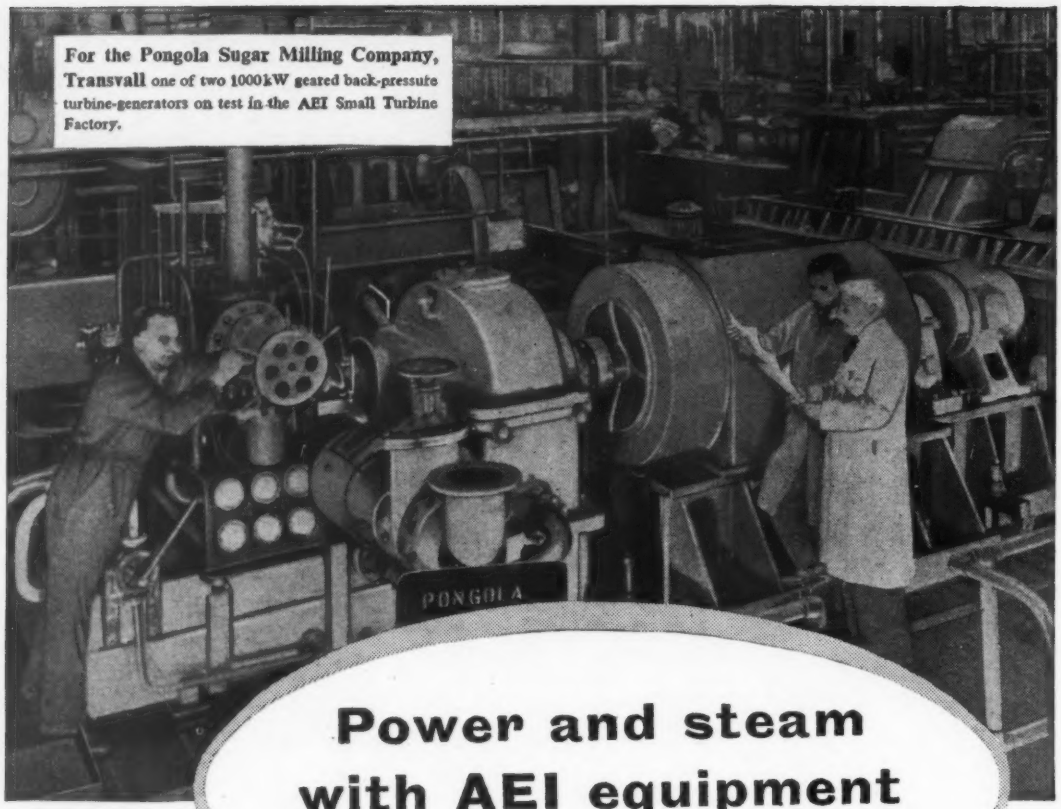

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Short Term Estimates of Load and Energy Requirements

THE PROBLEM OF FORECASTING FUTURE ELECTRICITY demand is not an easy one, but for a rapidly expanding country like India, it is one which must be tackled. India's industrial and other development obviously cannot proceed satisfactorily unless adequate supply of electricity is ensured during the coming years and this cannot be done unless probable future demand is known.

The following brief account of ways of forecasting electricity demands is based on methods developed and used at the Victoria State Electricity Commission in Australia. (For details about the S.E.C., Appendix I may be consulted). The figures and illustrations pertain to the S.E.C. However, the methods can be readily adapted to the Indian conditions by taking into account planned expected development.

Long term forecasts usually place emphasis on the annual maximum load and annual energy. Short term forecasts, for periods up to eighteen (18) months ahead, must be produced in much greater detail to be adequate for such purposes as the planning of plant maintenance programmes and the planning of the plant required to be available for service.

The detail required from short term forecasts are monthly estimates of peak and valley loads and at least sufficient estimates of load at other significant times to enable the complete daily load curve to be described. An estimate of the monthly week-day average load curve is particularly useful for operational planning.

As mentioned above, two types of forecasts are necessary, load forecast which governs required generator capacity, and the energy forecast, i.e., total kilowatt hours. The load forecast is based on the statistical processing of a sufficiently large sample of historical load data to allow the effect of daily weather and other fluctuations to be smoothed. The energy forecast also aims at smoothing out fluctuations. Those due to weather, in particular those of temperature, are smoothed by a more direct process of correlating temperature with energy.

No account is taken of any abnormal local demand arising out of new decisions for placement of big factories, etc. Such factors must be considered separately and their effect can be incorporated in the forecasts fairly readily.

To allow the analysis to proceed satisfactorily, it is necessary to obtain a reasonably representative sample of data. Therefore, for a week-day load analysis it is necessary to exclude abnormal loading days, such as days of industrial trouble or holidays and the days immediately prior to and after the Christmas holidays.

Each of the two forecasts, namely, load and energy, can be handled in either of two ways, referred to below as the "Centred Moving Average" and "Temperature Correlation". However, for sake of brevity the former will be discussed in relation to load forecasts while the latter will only be applied to energy forecasts.

Load Forecasting—Centred Moving Average Method

Data required for load forecasting is deduced from a study of the daily load curve for the system, a typical one for a working week-day for the S.E.C. system is shown plotted in *Figure 1*. The salient times become at once apparent:—

- 0500 hours — valley (an attempt has been made in recent years to fill this valley by offering cheap night rate hot water service to consumers)
- 0815 hours — commercial, industrial and domestic peak
- 1400 hours — as a measure of afternoon load
- 1800 hours — domestic evening peak
- 2000 hours — summertime domestic peak, therefore not apparent in Figure 1.
- 2330 hours — night rate hot water service comes into operation.

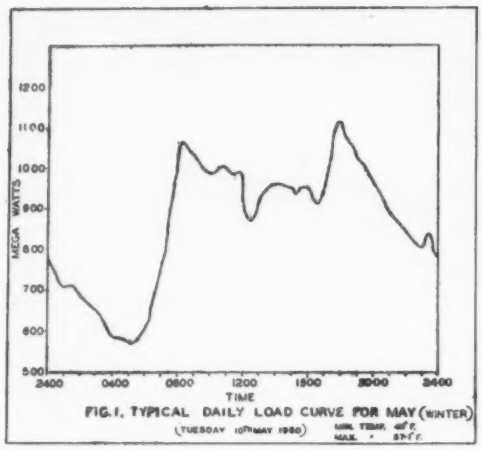

FIG. 1. TYPICAL DAILY LOAD CURVE FOR MAY (WINTER)

Preliminary Analysis

In practice all the peaks are considered, but for sake of simplicity, only the treatment of 0815 hours peak will be shown here.

1. Tabulate the daily load for 0815 hours in monthly groups for the past few years as shown in *Table 1*.

2. Calculate the arithmetical average x

2A. Also calculate standard deviation σ. This will be used later. See Appendix III.

$$\sigma = \sqrt{\frac{\Sigma x^2 - \left(\frac{\Sigma x}{n}\right)^2}{n-1}}$$

Procedure

(a) Tabulate the loads, i.e., x's as obtained under item 2. Obtain the centred moving average and the index I from the tabulation as shown in *Table 2*.

(b) Plot the monthly indices for all the years treated, giving a total of twelve graphs. Graphs for February, May, July and October are shown in *Figures* 2—5.

(c) Draw a line of best fit through the points as shown and extrapolate.

If the total of the extrapolated values of the indices exceeds 12×100, it may be necessary to level these indices. This may be done by plotting the extrapolated values of the indices as a time series and a ready means of smoothing will be apparent.

(d) Plot centred moving average figures (from Table 2), join and extrapolate. *Figure 6*.

(e) Obtain estimate for future by multiplying extrapolated centred moving average by appropriate levelled index I.

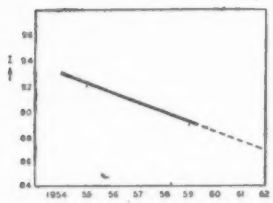
FIG. 2 MONTHLY INDEX FOR FEBRUARY

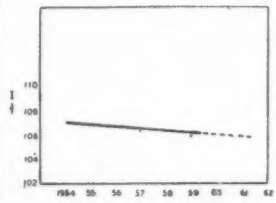
FIG. 3 MONTHLY INDEX FOR MAY

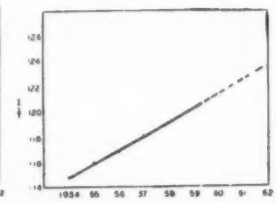
FIG. 4 MONTHLY INDEX FOR JULY

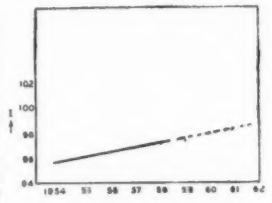
FIG. 5 MONTHLY INDEX FOR OCTOBER

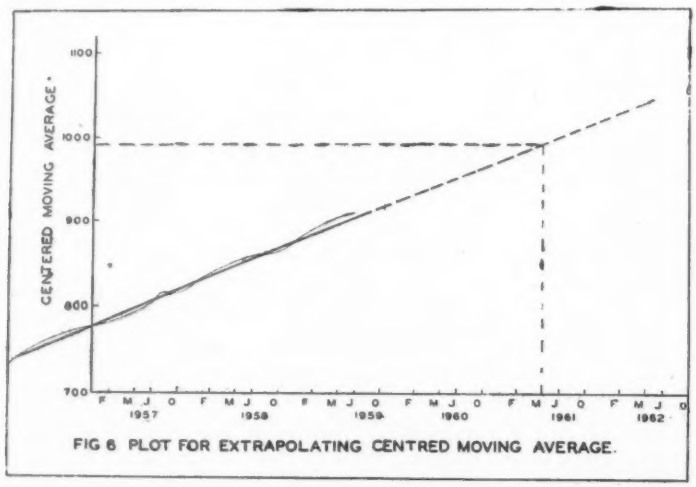

FIG 6 PLOT FOR EXTRAPOLATING CENTRED MOVING AVERAGE.

Example

Estimate for 0815 hours peak for May, 1961.

Extrapolated centred moving average = 992, Extrapolated index I = 105.9%.

$\therefore$ Forecast $= 992 \times 105.9\% = 1050$ MW

Note

The maximum load likely to be experienced in any given month may be estimated on the assumption that load variations from day to day follow statistically a normal distribution curve with mean equal to the forecast average value and standard deviation obtained by extrapolating its trend line to the year concerned. By planning for a maximum daily demand equal to "mean + 2 std. deviation" one would be conforming to common practice in statistical analysis of accepting a calculated risk of expecting an actual daily demand in excess of that provided for, about once in 20 cases. A reserve of plant over that required to meet the estimated Daily Maximum Demand would also be provided for in the usual way.

Energy Forecast—Temperature Correlation Method

The temperature correlation method, as the name suggests, is based on a more direct relationship between temperature and electricity demand. Therefore, in addition to obtaining (and tabulating as in *Table 3)* the week-day energy figures for past few years, the following figures for temperature must be obtained.

1. Dry/wet bulb daily mean temperature $\frac{(\text{max.} + \text{min.})}{2}$ from which a monthly arithmetic average is calculated.

Note :

Although it is considered that wet bulb temperatures may give better results, dry bulb temperatures are used in the S.E.C. because records and processed data for dry bulb temperatures were readily available from the Melbourne Bureau of Meteorology.

2. Long term average mean monthly temperature for each month, i.e., average of figures in 1 above over several years.

Procedure

(a) Tabulate week-day average energy in column B, *Table 4*. Also fill in columns A and E for dry bulb mean monthly temperatures, and long term average mean monthly temperature respectively.

(b) Plot the week-day average energy figure for the month on a semi-log paper as shown in *Figure* 7. As expected, the crests and troughs of this plot will be seen to ascend each year and a straight line passing approximately through the troughs can be readily drawn and extended.

As the summer load is the minimum load of the year, any increase in load due to weather and seasonal variations can be expressed as a ratio of the average summer load. The straight line drawn as explained above can be designated as Base Energy line (base load line in the case of load forecasts).

$\therefore \dfrac{\text{week-day average energy}}{\text{base energy}} = R =$ function of temperatures.

(c) Columns C can now be filled in Table 4 by reading the figures off Figure 7.

(d) From columns B and C, calculate the ratio R to fill column D.

(e) Using columns A and D, plot values of R against corresponding values of mean monthly temperatures. Draw a line of best fit through the points. *Figure 8.*

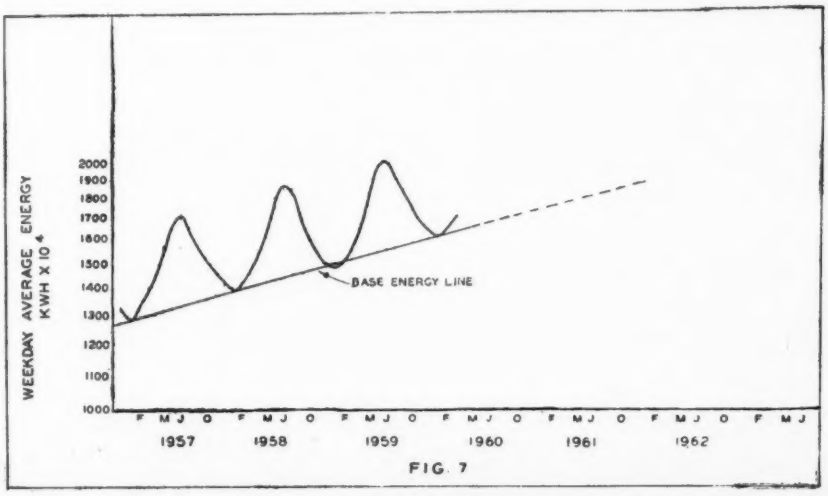

FIG. 7

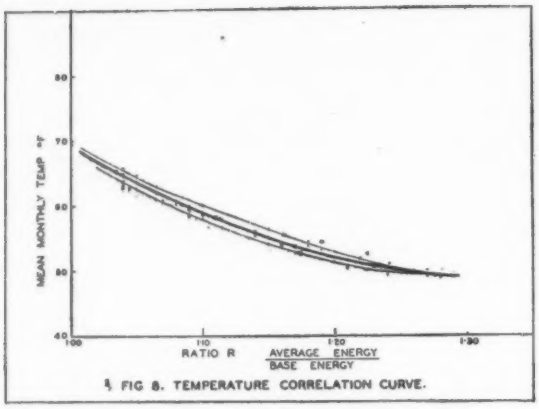

FIG 8. TEMPERATURE CORRELATION CURVE.

Note : It will be seen that the points are scattered. This led to some further examination and investigations, and it appears that the points corresponding to months January to July (shown by dots) in general fall on a higher level than those for August to December (shown by crosses). This indicates that perhaps "two lines of best fit" can be drawn (as shown faintly), instead of one. However, the results obtained by using two lines were not any better. Further work will need to be done before it can be established that "two lines of best fit" will give more accurate results.

(f) Corresponding to figures in column E, read off values of R from Figure 8, and enter in column F.

(g) Enter figures in column G, by reading off from Figure 7.

(h) Obtain estimate for future by multiplying figure in column G by that in column F. Enter in column H.

Example

Estimate for May, 1961.

Corresponding to long term average monthly temperatures for May of 54.3, R = 1.156 from Figure 8.

Base energy for May, 1961, from column G for 1961 is 1786×10^4 kWh.

$\therefore$ Forecast for May, $1961 = 1.156 \times 1786 \times 10^4 = 2060 \times 10^4$ kWh.

Further Comments

1. Although the centred moving average method is illustrated for load forecast, it can be similarly applied to energy forecasts. Equally the temperature correlation method may be similarly applied to load forecasting.

2. For comparison and interest, column J in Table 4 shows actual figures obtained from 1959 and part of 1960. It may be concluded that the forecast is accurate to within 1-2%, thus illustrating the efficacy of the method.

3. It must be realised that the techniques shown have been evolved over a period, and take into account local peculiarities relevant to the subject. No doubt, further refinements would be made in future as more information and experience are obtained.

4. The methods shown can, in principle, be applied to other places but local modifications may be necessary. Co-operation of the meteorological authorities is very important, not only in forecasting but daily load scheduling so that extra plant may be placed in service in anticipation of extra lighting or heating load.

5. The forecasts obtained by the methods illustrated herein are expected to be reasonably accurate up to about eighteen (18) months in advance.

Conclusion

It is probably true to say that in most forms of forecasting there is more art than science. However, the above procedures reduce the amount of personal judgment to a minimum and, therefore, can be largely carried out by more junior staff without detailed supervision.

Whilst the centred moving average method is somewhat simpler than the comparatively newer temperature correlation method, it is thought that the latter should give better results. However, both methods described are being tried on an experimental basis and neither of them has been finally adopted by the S.E.C.

Acknowledgements

The author wishes to thank Mr. W. H. Connelly, B.E.E., B.COM., M.I.E. Aust., Chairman of the State Electricity Commission of Victoria, for permission to publish this paper, and also Mr. A. F. Maguire, A.M.I.E. Aust., System Loading Engineer, Mr. G. Triggs, Grad. I.E. Aust., and Mr. C. Joyce, Grad. I.E. Aust., of the State Electricity Commission of Victoria for their advice in the preparation of this paper. The views and comments expressed in the paper are those of the author and not necessarily those of the State Electricity Commission.

Appendix I

STATE ELECTRICITY COMMISSION OF VICTORIA—SOME BASIC STATISTICS AS AT 30TH JUNE, 1959, (FOR YEAR 1958—1959)

(a) Installed Capacity of generators (interconnected state grid)

	Megawatts
Base load thermal stations (exclusively brown coal)	455.00
Peak load thermal stations (including diesel)	563.68
Hydro stations	261.52
	1,280.2

Not connected to state grid	24.55
(b) Electricity generated	kWh × 10^6
Interconnected system	5,485.5
Other S.E.C. stations	48.1
(c) Maximum coincident demand on S.E.C. interconnected system (MW) (10th July, 1959)	1,219.75
(d) Average kWh sold per head of population in Victoria	1,557
(e) Sub-division of electricity supply	%
Domestic	39.5
Industrial	38.0
Traction	6.0
Commercial	15.0
Public lighting	1.5
(f) Transmission and Distribution	Route Miles
220 kV	524.5
132 kV	80.5
66 kV	1,304.3
22 kV	12,334.7
12.7 kV *	3,451.5
11 kV	35.6
7.2 / 6.6 / 4.0 kV	636.5
Low Tension	10,473.0
TOTAL	28,840.6

* 27.7 kV corresponds to $\frac{22}{\sqrt{3}}$ and is the voltage at which the comparatively new country system, based on "single wire earth return system", operates.

Appendix II

The following points about Australian habits are summarized for interest:—

1. More electric appliances are used in the household than is the case in India. However, bulk of the load is due to electric heaters.

2. Hours of working are approximately:—

   (a) Factory workers: 8 a.m. to 4.30 p.m. with half-hour for lunch at 12 noon, and tea breaks at 9.30 a.m. and 3 p.m.

   (b) Office Workers: 8.45 a.m. to 5.00 p.m. with one hour for lunch at 1.00 p.m. and tea breaks at 10.00 a.m. and 3.15 p.m.

3. Based on the abovementioned hours of work, certain dips in the daily load curve (Figure 1) can be readily explained,

   e.g., the 0815 hours peak is due to factories starting up, plus some traction (electric trains trams) taking office workers to work.

   The 0930-1015 hours dip is due to morning tea breaks, first that of factory workers, then the office workers.

   The big drop at 1200 hours is the factories shutting down for lunch, and so on.

4. Metropolitan public transport system starts functioning at 0500 hours and ceases at about 0100 hours. A number of factory workers, living long distances away, start their daily chores as early as 0500 hours.

5. Most factories start shutting down for Christmas (the singularly important annual holidays) around mid-December and re-start about 10th January.

Appendix III

Basic formula for standard deviation is —

$$\sigma = \sqrt{\frac{\Sigma (x-\bar{x})^2}{n-1}}$$

$$= \sqrt{\frac{\Sigma (x^2-2x\,x+x^2)}{n-1}}$$

$$= \sqrt{\frac{\Sigma x^2-2x\,\Sigma x+n\,\bar{n}^2}{n-1}} \quad \text{since } x \text{ is constant}$$

$$= \sqrt{\frac{\Sigma x^2-2\bar{x}\,n\,\bar{x}+n\,\bar{n}^2}{n-1}} \quad \text{since } \bar{x}=\frac{\Sigma x}{n}$$

$$= \sqrt{\frac{\Sigma x^2-n\,x^2}{n-1}}$$

$$= \sqrt{\frac{\Sigma x^2-n\left(\frac{\Sigma x}{n}\right)^2}{n-1}}$$

$$= \sqrt{\frac{\Sigma (x)^2-\frac{(\Sigma x)^2}{n}}{n-1}}$$

TABLE I

0815 HOURS LOAD (¼HOUR MAX. DEMAND) IN MEGAWATTS - SPECIMEN TABLE FOR PART OF 1957

Date	*Sept.*	*Oct.*	*Nov.*	*Dec.*
1	—	987	728	—
2	919	922	—	785
3	873	891	—	762
4	833	826	738	767
5	798	—	*	756
6	750	—	746	741
7	—	834	784	—
8	—	806	773	—
9	783	764	—	744
10	799	757	—	760
11	782	798	762	760
12	779	—	753	743
13	771	—	761	742
14	—	792	742	—
15	—	774	720	—
16	925	767	—	—
17	900	784	—	
18	897	747	800	
19	885	—	797	
20	818	—	786	
21	—	739	761	
22	—	776	737	
23	769	836	—	
24	790	795	—	
25	804	788	755	
26	*	—	798	
27	859	—	781	
28	—	758	759	
29	—	761	726	
30	868	767	—	
31	—	751	—	
				Christmas — slackness and shutdown
Σ	16,602	18,420	15,207	7,560
n	20	23	20	10
$\bar{x}$	830	801	760	756†
$\Sigma x^2 \times 10^5$	138,397	148,327	115,743	57,171
S. D. σ	55.4	60.6	24.8	14

Notes:

1. Dashes (—) indicate week-ends (Sat., Sun.)
2. Asterisks (*) indicate public holidays.

† These are the figures which go into Column a of Table 2.

TABLE II

	a	b	c	d
	Average Working Weekday MW	12 months centred total	Centred Moving Average	Index I $\frac{a}{c}$ %
1956—Nov.				
Dec.		9323		
1957—Jan.	685		779	87.9
		9381		
Feb.	715		783	91.3
		9415		
March	733		787	93.1
		9470		
April	764		791	96.6
		9518		
May	844		794	106.3
		9548		
June	855		798	107.1
		9598		
July	949		803	118.2
		9665		
Aug.	906		807	112.3
		9707		
Sept.	830		811	102.3
		9747		
Oct.	801		815	98.3
		9803		
Nov.	760		818	92.9
		9824		
Dec.	756		824	91.7
		9956		
1958—Jan.				

Notes:

Column 'a'—Figures from Table 1.

Column 'b'—Each figure is a total for 12 months taking six months on either side of it, e. g., 9381 is the total for the period August, 1956, to July, 1957.

Column 'c'—$779 = \frac{1}{12}\left(\frac{9323+9381}{2}\right)$ etc.

Column 'd'—Index I is obtained by dividing the figure in Column 'a' by that in Column 'c'.

TABLE III

WEEKDAY ENERGY IN KWHRS X 10^4 — SPECIMEN TABLE FOR PART OF 1957

Date	*Sept.*	*Oct.*	*Nov.*	*Dec.*
1	—	1,789	1,395	—
2	1,590	1,701	—	1,406
3	1,576	1,636	—	1,465
4	1,529	1,510	1,410	1,448
5	1,491	—	*	1,422
6	1,474	—	1,451	1,405
7	—	1,546	1,507	—
8	—	1,472	1,477	—
9	1,469	1,471	—	1,387
10	1,472	1,508	—	1,444
11	1,440	1,576	1,434	1,427
12	1,456	—	1,458	1,450
13	1,410	—	1,426	1,426
14	—	1,428	1,411	—
15	—	1,448	1,379	—
16	1,711	1,486	—	—
17	1,667	1,478	—	—
18	1,694	1,403	1,548	—
19	1,624	—	1,571	—
20	1,525	—	1,484	—
21	—	1,441	1,429	
22	—	1,525	1,387	
23	1,453	1,579	—	
24	1,545	1,496	—	
25	1,530	1,475	1,459	
26	*	—	1,534	
27	1,582	—	1,501	
28	—	1.451	1,434	
29	—	1,477	1,392	
30	1,694	1,477	—	
31		1,423		
Σ	30,932	34,796	29,087	14,280
n	20	23	20	10
$\bar{x}$	1,545	1,512	1,454	1,428
$\Sigma x^2 \times 10^3$	48,022	52,828	42,362	20,397
S. D. σ	93	92	56	24

TABLE IV

	A					B					C				
	Dry Bulb Mean Monthly Temp. °F.					Weekday Avg. Energy kWh × 10^4					Base Energy (from Fig. 7) kWh × 10^4				
	'55	'56	'57	'58	'59	'55	'56	'57	'58	'59	'55	'56	'57	'58	'59
J	69.7	66.6	65.9	64.8	72.7	1104	1217	1284	1397	1460	1104	1184	1287	1387	1493
F	69.5	72.6	67.8	67.9	68.3	1131	1236	1342	1418	1518	1110	1197	1296	1399	1502
M	64.7	68.8	63.7	64.6	65.2	1168	1256	1367	1462	1554	1116	1201	1300	1402	1511
A	59.7	60.5	60.1	59.7	61.5	1224	1336	1405	1539	1620	1125	1209	1305	1412	1520
M	53.1	54.6	54.3	56.6	53.8	1342	1461	1550	1642	1801	1132	1218	1316	1426	1527
J	50.0	50.0	56.7	49.7	51.1	1425	1564	1559	1783	1952	1138	1227	1327	1437	1541
J	49.5	50.1	49.0	48.9	49.7	1442	1590	1702	1859	1999	1148	1238	1338	1448	1550
A	52.7	49.6	50.6	51.4	52.5	1407	1574	1636	1779	1909	1151	1247	1347	1451	1556
S	55.3	53.8	53.7	52.6	53.6	1315	1446	1545	1683	1833	1157	1251	1351	1463	1570
O	58.8	55.8	57.0	56.6	58.0	1274	1429	1512	1626	1760	1161	1256	1356	1473	1580
N	59.2	58.2	61.1	63.1	65.3	1267	1371	1454	1543	1658	1166	1266	1369	1480	1591
D	64.3	63.0	64.9	62.4	65.1	1251	1326	1423	1558	1655	1174	1276	1377	1491	1600

	D					E	F	G			H			J	
	Ratio R = average / base					Long Term Avg. Mthly Temp. °F.	R From Fig. 8	Base Energy kWh × 10^4			Forecast Base × R			Actual	
	'55	'56	'57	'58	'59			'59	'60	'61	'59	'60	'61	'59	'60
J	1.00	1.03	1.00	1.00	0.98	67.6	1.012	1500	1606	1740	1520	1625		1460	1606
F	1.02	1.03	1.04	1.01	1.01	67.8	1.011	1504	1620	1750	1521	1640		1518	1664
M	1.05	1.05	1.05	1.04	1.03	64.8	1.038	1511	1631	1756	1569	1691		1554	1691
A	1.09	1.10	1.08	1.09	1.07	59.5	1.092	1521	1645	1771	1661	1800		1620	
M	1.19	1.20	1.18	1.15	1.18	54.3	1.158	1531	1651	1786	1771	1911	2062	1801	
J	1.25	1.27	1.17	1.24	1.27	50.4	1.235	1540	1661	1799	1900	2050		1952	
J	1.26	1.28	1.27	1.28	1.29	49.1	1.285	1549	1674	1804	1989	2150		1999	
A	1.22	1.28	1.21	1.23	1.225	51.0	1.225	1552	1688	1816	1900	2063		1909	
S	1.14	1.16	1.14	1.15	1.17	54.3	1.158	1561	1699	1832	1809	1965		1833	
O	1.10	1.14	1.12	1.104	1.11	57.9	1.111	1577	1704		1752	1892		1760	
N	1.09	1.09	1.06	1.04	1.04	61.3	1.072	1590	1713		1709	1840		1658	
D	1.07	1.04	1.04	1.045	1.035	65.0	1.035	1599	1730		1654	1785		1655	

Aluminium from Canada assists in India's power projects.

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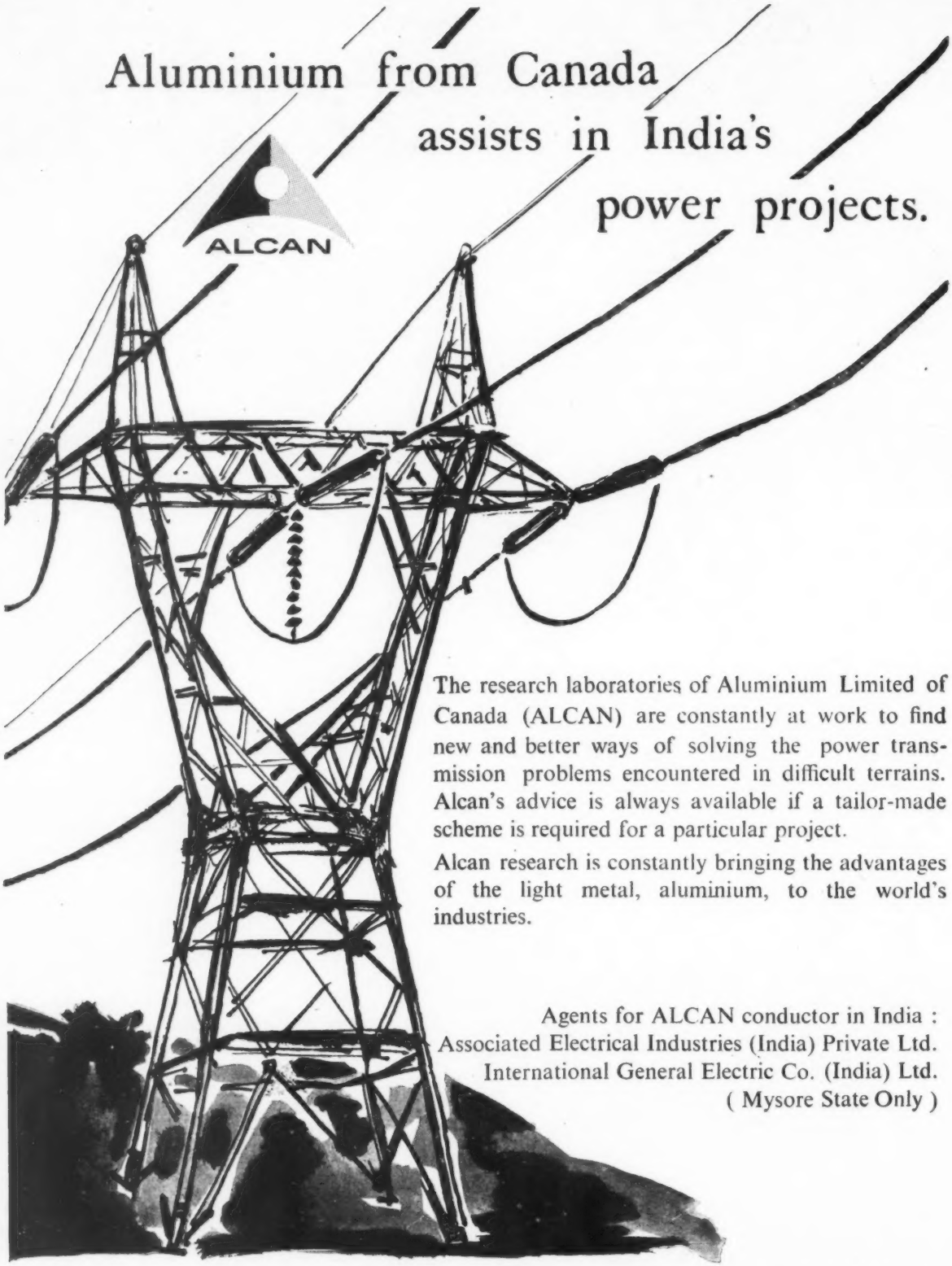

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Commercial Engineer
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Establishment of Super-Grids and Organisational Procedure for their Control

OUR COUNTRY IS AT PRESENT AT A LOW LEVEL OF industrial development. Even then there is a shortage of power supply all over the country. As far as we can foresee the shortage is going to be with us for a number of successive Five Year Plans. In the immediate future one of the main difficulties in the Third Five Year Plan will be the shortage of power supply for major industries. It will be very difficult to construct generating facilities fast enough to keep pace with the growing demand. However, new generating units are not the only source of additional load carrying capacity. An amount of effective load carrying capacity can be made available by suitable interconnection, which will constitute a far larger addition to the power resources than is generally recognised. If intelligently planned and located, if carefully co-ordinated with existing facilities and if operated with full effectiveness, such interconnections will not only create substantially new load carrying capacity but they will do it quickly without serious inroads upon our meagre economic resources. They will make both existing and new capacity available in other wider areas.

Our country is a large one and the resources of power generation and the other natural resources and facilities for industrial development are not necessarily located very near to each other in all cases. It will be always economical to generate power where the natural resources like hydro-electric potential or the coal mines occur than to generate them in small generating stations near the load centres. If large power stations are located far between and some distance away from the load centres the only right way of providing a uniform and stable supply will be to interconnect them in zonal grids. It is needless to repeat that by construction of zonal grids economy will be gained by the way of saving in fuel and saving in the provision of stand-by power. The regional grids should at a next stage be connected to adjoining regional grids across State frontiers or borders of the regional areas. These zonal grids and the interconnections on the basis of the developments in the foreseeable future should operate at 220 kV 3 phase 50 cycles A.C. The trans-continental national system interconnecting giant hydro stations in the Himalayas and the Western Ghats and on the mighty rivers on the Central Plain with the super-thermal stations in the coalfields of Bihar, West Bengal and Central India and Lignite fields of the South India and also the Nuclear Power Station in the Western India operating at a super high tension D.C. system is an ideal worth striving for. In the present context of development, however, such an idea may be stated to verge on the utopia and may be left out of consideration.

The first step in this direction should be the organisation for construction of zonal power grids on which some thought has already been exercised by the competent authorities, like the Central Water and Power Commission. The small zonal grids are already in operation with limited extent. Mention may be made of the Madras System, Bhakra Nangal System and the D. V. C. Power System. These grid systems, however, grew out of the needs of the region and not so much as a result of conscious planning for integration into an interconnected grid all over the country. Once we fix the objective of having national grid, or it will be more correct to say an interconnected system of zonal grids, then the main task will be to foresee and set the pattern of grid so that each regional grid can grow into it in an organic sense.

Zonal Grids

Let us examine the benefit that will accrue if we establish zonal grids before we go further into the benefits that may accure on a higher stage of development of the national interconnected grids. That it will result in economic saving by way of capital investment by establishment of large central stations in preference to small local stations and by the way of fuel cost by higher efficiency of the largest staions will not disputed by anybody. The economic benefit as a result of pooling the standby power will require more careful scrutiny.

To make the problem simpler let us take the example of a section of the Eastern Zone in order to assess approximately the benefits that might accrue to the Zone as a whole if zonal grid is established. The table-I given below may be seen.

TABLE—I

A STATEMENT SHOWING INSTALLED CAPACITY, FIRM CAPACITY AND STANDBY POWER OF MAJOR POWER SYSTEMS AND STATIONS IN WEST BENGAL, BIHAR, ORISSA AND D.V.C. (IN mW)

	1965 - 1966		
WEST BENGAL	I.C.	F.C.	S.P.
(a) *Utilities*			
1. Calcutta Electric Supply Corporation	432.3	310.0	122.3
2. Gouripur Electric Supply Company	47.4	28.7	18.7
3. Dishergarh Electric Supply Company	16.0	11.0	5.0
4. Seebpur Electric Company	8.4	5.4	3.0
(b) *Industries*			
1. Aluminium Factory	15.3	10.0	5.3
2. Durgapur Steel Plant	15.0	10.0	5.0
3. Indian Iron & Steel (Burnpur & Kulti)	72.35	37.0	35.35
4. Durgapur Coke Oven Power House	180.0	120.0	60.0
	786.75	532.1	254.65
ORISSA			
(a) *Utilities*			
1. Hirakud System	270.0	184.0	75.0
2. Rajgangpur Steam Station	5.7	3.2	2.5
3. Chowdwar Steam Station	5.0	3.0	2.0
4. Supply from Machkund	—	27.9	—
(b) *Industries*			
1. Orient Paper Mills	10.75	6.25	4.5
2. Hindusthan Steel Ltd.	75.0	50.0	25.0
	366.45	274.35	109.0
BIHAR			
(a) *Utilities*			
1. Barauni	100.0	50.0	50.0
2. Patna Electric Supply	11.7	4.9	6.8
3. Sijua Electric Supply	14.0	9.0	5.0
(b) *Industries*			
1. Jamadoba Colliery P/H	13.5	6.75	6.75
2. Dalmianagar	22.0	16.0	6.0
3. Tata Iron & Steel	120.5	54.0	66.5
4. Indian Copper Corporation	8.0	4.0	4.0*
5. Sindri Fertilizer	80.0	53.0	27.0
	369.7	197.65	172.05
D.V.C.			
D.V.C. Power System	729.0	534.0	195.0
TOTAL:—	2251.9	1538.1	730.7

* Will close down ultimately

Only the States of Bihar, West Bengal and Orissa including the D. V. C. area have been taken into consideration. This incidentally represents industrially most developed and at the same time most acutely power starved area in the country. All the Public Utilities and the industrial power stations in West Bengal and Bihar listed in the table except for Jamadoba Power House and the Barauni Power Station, which is yet to come into being, are in some way or other already connected to the D. V. C. Power System. It will be a practical proposition to interconnect the power stations in Orissa into a Sub-Zonal Grid and connect that also to the D. V. C. System. In fact, a limited interconnction is already being effected for the purpose of power supply to the Railway Electrification Project. If all these interconnecting links are made more stable and of higher capacity this can form the basis of a Zonal Grid in Bihar, Orissa and West Bengal. This could in future be extended and interconnected with Assam and Manipur.

According to the study carried out by the Central Water & Power Commission as published in the "Forecast for Power Demand in India—1955-56 to 1970-71", from which the Table has been compiled taking into account only the major power stations, there will be 2252 mW of installed capacity in 1965-66 and the corresponding total of the firm capacities of the independent power stations and the systems will be 1538 mW. Aggregate of the system demands in these areas will be of the order of 2480 mW, which means that a shortage of about 900 mW, will occur in that region during the last year of the Third Plan. If all the power stations and the power systems listed above are interconnected in a grid and operated and maintained in a co-ordinated manner the available firm capacity will be increased considerably and the shortage reduced correspondingly. Considering that a thermal unit takes about two months for over-hauling and maintenance and a hydro generating unit takes even less time the standby for overhaul and maintenance, not counting the spinning reserve capacity which luxury we will not be able to afford for some time to come, should be somewhere about 1/6th of the installed capacity of about 250 mW, whereas the present standby capacity provision is of the order of 730 mW. This means that if adequate interconnection and co-ordination in the operation and maintenance are effected the available capacity could be increased by about 500 mW, which in terms of capital investment would mean a value of about Rs. 50/- crores and in the way of annual gross earnng about Rs. 10.80 crores. Similar benefits could

perhaps be shown if we considered any other zone.

A more specific example of the benefit that can accrue through interconnecting two systems can be given. The West Bengal Government has installed a thermal generating station at Durgapur as an adjunct to their Coke Oven Plant consisting of two units of 30 mW each. This station operating independently could provide a firm power of 30 mW only. As a result of interconnection with D.V.C. Power System and co-ordination of overhauling programme saleable capacity of this power station has been doubled. It will thus be seen that by establishment of the zonal grids the electrical and industrial development of the zone will be accelerated and the country as a whole will be benefitted economically.

Interconnection between Zonal Grids

There is no important interconnection between Zonal or State grids operating in our country. Therefore, assessment of benefits of interconnection is not possible. Interconnections between the DVC System and Rihand power system and between the DVC System and Hirakud System will be effected to serve the Railway Electrification Project. But the interconnection will be of a very limited nature and no large scale interchange of power is being contemplated at present. However, interconnection between power systems has been practised for a long time in the U.S.A. and for the last eight years in an organised way in Europe. Considerable knowledge and experience have been gathered which will be available to us. The benefits have been carefully assessed which are reviewed below:—

(1) Saving in generating capacity: The load diversity may arise from difference in shape of seasonal or daily load curves. This difference in turn arising from such causes as different proportion of urban and industrial loads, large proportion in one Zone of seasonal industries such as irrigation pumping or processing crops, etc., this type of load diversity, arising from differences in shape of load curves, may be called 'Scheduled Diversity'. Load diversity also arises from condition that even during the heavy load season the peak loads on any system usually vary considerably from day to day and from week, to week, while similar peaks in a neighbouring system are unlikely to occur in the same days or weeks. In other words, casual deviations up and down from the average trend of daily peaks in one system are likely to offset rather than superpose upon similar casual deviations of other system of an interconnected load. This second type of load diversity, which may be called 'Casual Diverseity', is probably more important. A considerable saving is likely to be effected by sharing the peak-load of one system by the other.

(2) Saving in generating capacity by reason of diversity in demands upon reserve facilities: It is unlikely that emergencies will occur simultaneously in two or more systems and it is also possible to co-ordinate the maintenance and inspection schedule of different systems. As a result, it is possible to reduce the total reserve capacity available between large systems. This saving is likely to be very significant.

(3) More effective use of surplus generating capacity in one system can be available for unexpected load increase in any of the interconnected systems.

(4) Economy interchange: Savings in production cost are possible whenever and for so long as one system might otherwise have relatively high-cost capacity in use and in other system at the same time would have lower-cost units idle or partially loaded. In addition to direct savings from economy interchange, further savings result from greater steadiness of turbine and boiler loadings and from greater precision in scheduling loads upon units and stations.

(5) Staggering and rotating in development of new capacity in several systems: In some cases this obviates temporary over-development and saves capacity, and in other cases it makes feasible the installation of larger and more economical generating units and saving in capital investment and operating cost.

(6) Opportunity for inter-system firm power sale.

(7) Mutual protection against extraordinary breakdowns, fuel shortages and other emergencies.

(8) Improvement to service, in some cases, in outlying portions of the systems between which interconnection is made.

(9) Where hydro generation is involved, still further savings in capacity and in operating costs may accrue from diversity in stream-flow characteristics between different watersheds, from more effective use of water storage, from more complete utilisation of dump energy during flood season and, in particular, from more complete development of low load-factor hydro installations for the carrying of high short peaks for a group of interconnected systems and for short duration emergency service.

The Nature of Transactions in Interconnected Operation

The nature of transactions in interconnected operation will not be examined in detail in this paper. They will naturally cover the types of benefits enumerated in the preceding paragraphs. Only it is intended to emphasise here that in most types of interconnected arrangement the realisation of expected benefit requires co-operation and co-operation cannot be imposed or compelled. It implies sincerity in devotion of the joint objective of the best overall result, willingness to accept a fair break where there is diversity of interest and confidence in similar integrity and fairness of the other side.

The interconnections with the co-operative projects involving independent zonal grids operating each

with its own management and each with its separate responsibilities to the welfare of the area it serves, the service in one system may become partially dependent upon the condition in another and realising all the responsibilities the benefits will depend upon the future effective co-operation between the independent organisation. Hence, the management of the respective zonal grids will face important issues in setting up the agreements which will establish their respective obligations and rights in such a co-operative project.

The contractual procedure established should be such as to make co-operation easy and to set up as few hurdles as possible. Basically except as firm capacity transaction, if maximum aggregate benefits are to be attained, the benefit to each party individually should be derived primarily from the value to it of the services which it receives, not from the profit on the services which it supplies. This is very important. The free inter-system flow of services should not be checked by fixed rates and tolls, rigid terms of settlement, or arbitrary margin of profit to the sending party. Such features can be barriers in the way of transaction through which alone potential benefits are realisable. The relation between the partners in an interconnection is that of mutual assistance between procedures and not that of sale by producer to consumers of distributors. Such reciprocal transaction between producers may often be on incremental basis. No proper inference can be drawn that similar terms would be suitable where such reciprocal situation does not exist.

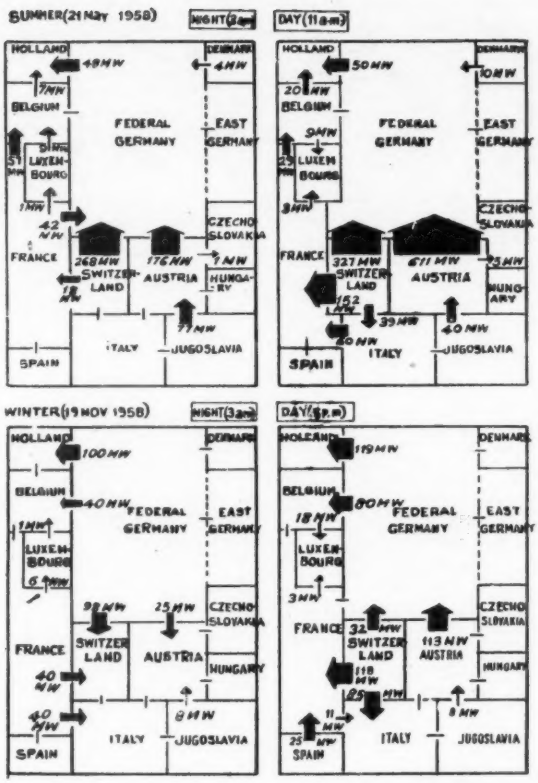
The condition under which inter-change services are supplied to some degree the nature of services themselves will vary from time to time during the period of long term interconnection agreement. Hence, provision of the agreement should cover objectives, procedures for accomplishing objectives and general principles of settlement and this should embody flexibility to meet the changing condition and to avoid rigid prescription of detailed arrangement at least in so far as practicable, consistent with reasonable protection to individual interests of the parties and consistent with the securing of legally valid enforceable contract.

The "operating committee" should be an important feature in this agreement. The "operating committee" should be an authorised agent as to the operating arrangement of the transaction covered by the agreement, and should also be authorised to arrange for individual transaction not covered by the specific terms in the agreement. The flexibility in the interconnection arrangement involves sufficiently broad responsibilities for the "operating committee", contractual provision under which adjustment for changed condition may be made without adjusting the basic contract terms, all practical precaution against stalemate in effecting the needed adjustments, relatively short effective terms initially for arrangement for certain terms of transaction as to which neither party is likely to be handicapped in working out subsequent arrangement, and in some cases, back-up provision not normally applicable but which comes into effect in certain contingency until other arrangements are made. A way should be opened to carry out under the agreement rather than outside of it, advantageous special transaction not covered by specific arrangement in effect at that time.

Experience of Other Countries

The benefits that will be derived and the nature of transactions which are generally involved in interconnection between the grid systems has been stated briefly in the preceding paragraphs. It will be of benefit to review the recent experience of more developed countries on whose abundant stores we may gratefully draw upon. Interconnections have been practised for years in the United States and for sometime in the European continent. The interconnections effected in the U.S.A. were largely between old established power supply undertakings of a very large magnitude. Although the European development is also considerably larger than ours, the magnitude and expanse bear a closer comparison than with the U.S.A. A study of the experience of the European practice may be of more immediate benefit to us.

Economic co-operation of Europe's Power Supply System through completely voluntary international co-operation is the object of the Union for the Co-ordination of the production and transmission of electrical power (UCPTE). This organisation was founded in OEEC auspices in 1951. Eight countries take part in its operation—Austria, Belgium, the Federal Republic of Germany, France, Italy, Luxembourg, the Netherlands and Switzerland. It is very likely that United Kingdom will join as soon as the Cross Channel Cable Project comes to fruition. The administration of the Union is remarkably informal. The Presidents are chosen among full members for a two-year period and the State to which the President belongs provides a Secretariat. The Union facilitates arrangement of power transfers across international frontiers as a means of balancing supply and demand between systems with different characteristics. For example, in 1953, an unusually dry weather resulted in serious difficulties of power in Bavaria during the following winter. Power transfers from Italy as well as Rhineland were arranged from November of that year to the following January and allowed the gap to be bridged without significant restriction. Again in the cold of February of 1956 when Austria, Italy and Switzerland were faced with serious supply position Germany was able to help balance supply and demands. The chart attached in Fig. 1 and table-2 will show the pattern of the ex-



Typical day and night power flow across national frontiers UCPTE system are shown here. Bars without arrows show that transmission lines cross the frontiers, but were not loaded at the particular times to which the load flow diagrams refer.

FIG. 1

change. It will be seen that in 1958 nearly 3 million kW were exchanged between different countries and 50% of the capacity for the international tie lines were utilised.

The interconnected system is operating largely at 220 kV. It will be of interest to note that the UCPTE has as a matter of policy avoided recommending erection of a transmission system superimposed on the existing systems of member countries. The feeling was that ironing out of differences in daily and seasonal curves would be better carried out by trans-frontier connecting lines at appropriate voltages.

To facilitate its working the Union has two working groups in operation. One deals with thermal stations, arranging co-ordination of overhaul and repair as well as discussing operation problem of thermal stations. The other working party deals with transmission question giving particular attention to technical problems of interconnecting large systems. There is a further committee which discusses the situation of the power industries in the eight countries

TABLE—2

MAXIMUM LOADS EXCHANGED ON AT LEAST FOUR DAYS WITHIN A FORTNIGHTLY REPORTING PERIOD (IN mW)

Countries involved	1955	1956	1957	1958
1	2	3	4	5
France-Belgium	95	85	85	90
France-Luxembourg	10	10	10	10
France-F.R. Germany	115	155	125	155
France-Switzerland	290	335	270	370
France-Italy	70	80	135	140
Belgium-Netherlands	75	80	140	140
F.R. Germany-Netherlands	165	210	220	185
F.R. Germany-Belgium	85	140	160	190
F.R. Germany-Switzerland	260	275	470	635
F.R. Germany-Austria	660	745	720	830
Italy-Switzerland	100	90	140	110
Italy-Austria	20	100	130	90
TOTAL	1,965	2,330	2,630	2,980
Transmission capacity of international tie lines-total (mW)	3,901	4,367	5,122	5,922
Utilisation coefficient (%)	50.5	53.5	51.5	50.3

in the broadest way against future outlook. These committees have carried out various tests and formulated a number of recommendations for consideration of the members, which will be of interest if we desire to plan State and Regional Grids to be interconnected in future. Many of these suggestions if implemented now, or kept in view while planning the grids, the designs of the present may be amenable to changes for their adoption, considerable economy may be effected in interconnections in future.

(1) Elimination of load limiters on hydro turbine with introduction of an auxiliary control system permitting the turbine governor to respond to frequency variation but restoring the turbine open to the programme value after a pre-set time.

(2) Cutting-out the dash-pot on hydro turbine governor immediately after the generator has been switched on to the line.

(3) Increase of the governor sensitivity, possibly by using electrical turbine governors.

(4) Use of electrical regulators in steam stations permitting control of turbine and boiler so freeing control from delaying effect from admission pressure control and so increasing sensitivity.

(5) Provision of controllers operating on the number of combined frequency-load control for industrial power station feeding into power supply net-work so that this can contribute to frequency maintenance.

Suggested Pattern of Development

National or State Grids and Interconnected System of power grids have been developed with profit by other countries in the world. There seems to be no reason why zonal grids and subsequent interconnection thereof will not be established in our country. This is no longer only a desirable development but an imperative and immediate necessity if we are to conserve our limited resources and derive most benefit from the investments in the form of material and labour.

A look at the map, which is taken from the Power Atlas Figure 2 published by the Central Water and Power Commission, will indicate the nature of power development that is taking place in our country. It will be seen that local grids are already in the process of development. It will also be noted that they are not following a definite pattern. It will be too risky to hazard a guess on the pattern of inter-zonal connections that will take place or that should take place in the future. It will require a more extensive co-ordinated study with the future demand and available resources. Some spade work has already been done in this direction by the Central Water and Power Commission.

The benefits that will accrue to the country as a whole and to the zones by building interconnected zonal grids have been reviewed. We have also reviewed the nature of business which is being carried on in other countries especially in Europe, which we feel will suit our pattern of national polity. It is for consideration what type of organisations will be necessary in our country to develop and control the zonal grids and for operation of the interconnected zonal grids.

Electricity in our Constitution is a subject on the concurrent list. The Central Government in practice, only exercises legislative and regulative powers. Power supply in the Public Sector is either owned by Municipalities or the State Governments. Only notable exemption was in the case of Damodar Valley Corporation Power System in which a Central Law was enacted by the Parliament with consent of the two Legislatures for the purpose of unified development of a River Valley which spans the areas in two adjoining States of Bihar and West Bengal. Incidentally this River Valley with its adjoining areas is also the seat of major industrial development in this country. It will not be wrong to say that this Corporation has rendered signal services to the industrial development in the area by developing a power system beginning from nothing in 1948 to a system comprising a generating capacity of nearly half a million kW. An important private sector exist in utility business but public power being our national policy the organisation of the grids will be simpler. We have another advantage over Europe in the matter of developing the power grids. In Europe the national grids had to respect the international boundaries. In our country given the goodwill, there will be no such barriers in planning grids across inter-State boundaries. The large established systems in the private sector utilities and industries can also be fitted into future power grids.

It is possible for the power grids to follow different patterns; but it will be a great advantage if the choice is known and the pattern is set out in advance.

(a) It can take the form of small power systems emanating from well developed industrial region gradually covering a State by spreading over the undeveloped areas and being connected to each other; or

(b) Each State can have its own State Grids under the control of State Electricity Board; or

(c) There can be Zonal Grids consisting of more than one State; or

(d) There can be parts of a national grid system managed and supervised by a Central Authority.

If we consider the different patterns of development suggested above we will see that the first one, i.e. a system spreading out from an industrial centre, is the pattern of development which is taking place today. This obviously is not satisfactory enough if the service is to be made available to the country at large and the industries be spread out evenly over wider areas. From the point of view of the State political interest the second pattern of the State Trades owned by the State Boards will perhaps be most acceptable. The most economic and effective development of a power grid should follow the distribution of natural resources and location of load centres. If a fetish is made of the political boundaries of the States the national interest will be harmed. The exclusive State Grids will not be the likely best solution technically or economically. If it be possible to plan a national grid under a central agency and manage it efficiently it should be the best pattern. But an all India Grid will be too difficult to plan, more difficult to execute and too unwieldy to operate. Politically perhaps it will be the least acceptable to many. The most economical and practical proposition will be establishment of Zonal Grids across State boundaries with mutual consent and co-operation of the State Governments and operating under Zonal authorities. The Zonal Grid should be so planned that they could be easily interconnected with each other at convenient points and operated and controlled in a co-ordinated manner. A further study of European and American practice and experience will be of benefit.

These Zonal authorities may be incharge of generation and bulk transmission only, the constitution of which we will discuss a little later. The activities of this Board will not be in conflict, but only supple-

MAP OF
INDIA
VII - SEMINAR
SHOWING THE GROWTH OF POWER TRANSMISSION SYSTEMS
SCALE:- 1 INCH = 192 MILES
NOTE
ONLY TRANSMISSION LINES OF VOLTAGE 66 KV. AND ABOVE ARE INDICATED. NUMBER OF CIRCUITS OF TRANSMISSION LINES ALONG THE SAME ROUTE ARE NOT SHOWN. ADDITIONAL TRANSMISSION LINES PROJECTED FOR CONSTRUCTION TO REINFORCE THE CAPACITY OF EXISTING LINE IN THE SAME ROUTE ARE ALSO NOT SHOWN.
WEST PAKISTAN
NEPAL
Sikkim
BHUTAN
EAST PAKISTAN
BAY OF BENGAL
ARABIAN SEA
Bhakra
Nangal
Yamuna
Ramganga
Sarda
Umtru
Malanjkhand
Satna
Gandhisagar
Kahni
Rihand
Bokaro
Korba
Hirakud
Khaperkheda
Ukai
Purna
Ramagundem
Machkund
Koyna
Tungabhadra
Nellore
Madras
Jog
Bhadra
Kundah
LEGEND
Existing power line above 66 K.V.
Future power line above 66 K.V.
Existing power line 66 K.V.
Future power line 66 K.V.
Existing power Station (main)
Future Power Station (main)
Existing sub station (main)
Future sub station (main)
NOTE :-
Portions of the Indo-Pakistan boundary shown on the map have not been demarcated as an international boundary such alignments therefore are to be regarded as approximate not authentative.
Sikkim and Bhutan are attached to India by special treaty.
64°
68°
72°
76°
80°
84°
88°
92°
96°
100°
104°
108°
32°
28°
24°
20°
16°
12°
8°

mentary to the activities of the State Electricity Boards. Great Britain after years of experience have separated the authorities for generation and distribution. The generation is in the hands of a Central Generating Board and distribution is undertaken by the area Boards. In our country also the generation and bulk transmission could be undertaken by Zonal Boards and the distribution may be carried out by the State Electricity Boards. A Central Generating Board may not be suitable to an extensive country like ours. The division of labour will be of great benefit to the electrical development of the country. It must be remembered that according to the present reckoning the power generating capacity will be doubled in every 10 years in the country as a whole and it will be doubled in every 5 years in some of the industrial areas like that served by the Damodar Valley Corporation. Distribution of this large amount of energy will be the real crux of the problem. Setting up large generating stations and a big transmission system is a relatively simple matter. Distributing this larg amount of energy over the far flung areas and distant towns and villages and reaching to the doors of the domestic consumers and small industries is a colossal task requiring tremendous efforts which should be enough to occupy the whole energy of a State Electricity Board. It should feel relieved if the additional burden of large scale generation and transmission is taken over by a Zonal authority.

Development into a higher order of organisation always entails certain amount to sacrifice of sovereignty of the constituents if such a development is to be a success and effective. The Zonal grids if constituted should have a full right and obligation of supplying power in the area which will be included in its control. The State Board will have to forego its right in this sphere. The Zonal authority should not only have the power to generate and transmit the necessary amount of electrical power and supply it in bulk at high voltage to the State Electricity Boards and other large consumers or distributing authorities, but they must also have the *full responsibility of supplying any amount of power which it is called upon to supply in any point in the area it serves.* If the Zonal authority assumes this responsibility and it is enabled to fulfill it then the objections from different States which it will serve about the possible discriminations in the rate of development will be largely allayed. The responsibility of distributing the power to small consumers—industrial and domestic—and also development and location of industries will rest with the State Governments, the State Electricity Boards, the Planning Commission and other competent authorities. The Zonal power generation boards will have the responsibility of generation and making available to the State Electricity Boards and the industries in the area any amount of power required by them whenever it is required and wherever it is required. There should be no modification of this responsibility.

Constitution of Zonal Board

The Zonal Board should be an autonomous authority consisting of a number of members appointed by the President with the consent of the State Governments, areas of which it will serve. The members so appointed should serve during the pleasure of the President, normally during their full service period. The members should be full-time workers devoting their full attention to the operation of the Board. The Board should have power to finance its own schemes and sale power at reasonable profit. The part of the capital required by the Board may be lent by the State Governments or the Central Government; but the Board will normally raise money in the open market and liquidate the load at its own discretion. Although the Board should be at liberty to sell power at a reasonable profit and use the profit at its own discretion the profit thus derived should not ordinarily be allowed to be used for any other purpose than the extension to the power supply facilities..

When a Zonal Board is set up the State Electricity Boards should delegate their function of generating power to the Zonal Boards in the areas served by such Boards.

Constitution of the Committee for Interconnected Zonal Grids

It should be possible to manage the operation of the interconnection of the Zonal Grids by setting up a committee in the nature of the UCPTE operating in Europe. This organisation in our country may be closely associated with the Central Water and Power Commission, but should not be a part of it. The Committee may consist of one representative from each Zonal Board and each State Electricity Board and also one from the Central Water and Power Commission. One of the members will be elected Chairman for two years in rotation. The organisation which contain the Chairman will provide the Secretariat. The details of business transactions between the different zonal authorities will be as between the zonal authorities as independent commercial organisations. But they will follow the pattern set out by the Committee.

Conclusion

It has been shown that the establishment of Zonal Grids and interconnections between them will be very desirable and of economic benefit to the country.

The best pattern of development of power supply in this country will be to set up autonomous Zonal authorities vested with the power and full responsi-

(Continued on page 30)

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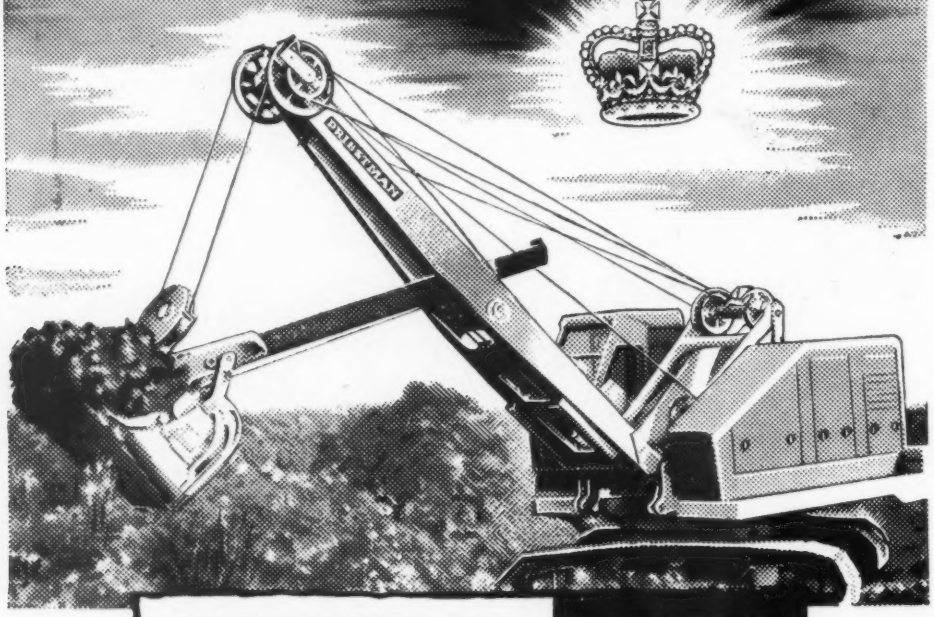

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TIIP/143

New Dam will bring Prosperity to U. S. Desert

GLEN CANYON, A DEEP GORGE OF THE COLORADO River in northwest Arizona, is the site of the largest construction project in the United States today. There, between sheer sandstone cliffs flanking the river, men and machines are building the nation's second biggest dam for production of electric power and storage of water for irrigation. High above the dam, they have built a steel arch bridge that links the canyon area with the nation's highway system. These structures are reshaping the face and future of a potentially valuable region of western U.S., often described as America's Last Frontier.

Glen Canyon Dam is the major structure in a program designed to benefit the Upper Colorado River Basin, a 4,000,000-acre Rocky Mountain plateau encompassing portions of the states of Wyoming, Utah, Colorado and New Mexico. The area is rich in mineral resources, has soil adequate for crops, but is low in rainfall, water-storage facilities and electric power. Its rivers and streams, flowing through deep rocky courses, feed melting Rocky Mountain snows into the Colorado River. The construction program in the Basin, which will include the large dam in Glen Canyon, four smaller dams on tributary rivers and 11 irrigation units, will store the water run-off and produce power for distribution throughout the entire plateau.

The four dams, small power plants and many irrigation units north of Glen Canyon are of conventional design and were simple to build, but the project in the canyon presented difficult engineering and construction problems. Glen Canyon is like the stem of a gigantic funnel through which water from the upper basin flows at the rate of 380,000 feet per second during spring run-off. From rim to rim, the gorge is 1200 feet wide, but without a bridge, the distance by road totals 225 miles. The river is bounded by sheer impassable rock walls 700 feet high. Engineers faced the fact that the only access to the canyon floor is from the air. To build a dam and power plant, everything would have to be lowered into the canyon—thousands of workmen, 50 tons of machinery and all construction materials, including 35,000 tons of steel and five million cubic feet of concrete.

Transportation in, out and across the gorge was solved by building a complex two-track cableway suspended between rail-mounted towers atop the sandstone cliffs and a temporary suspension bridge between the canyon rims. Now, the steel arch bridge is completed, enabling vehicular and pedestraian traffic to flow rapidly across the gorge. Several new cableway systems have been constructed to hasten delivery of materials into the canyon, particularly concrete.

Today, concrete is being poured from overhead to build the huge dam, which will be 1500 feet wide and will reach almost to the top of the canyon walls. In design, the dam is a gravity-arch structure that will utilize both its weight and design for strength. It will vary in thickness from 300 feet at the base to 35 feet et the crest. To distribute stress, the structure is made of columns or blocks with radial and circumferential contraction joints. The pre-cooled concrete, delivered by cableway, is being further cooled by refrigerated air flowing through 950 miles of pipes embedded in the dam. When completed, the structure will be only 26 feet lower than Hoover Dam, the nation's largest, which is 370 miles downstream on the Colorado River.

Concrete footings already have been poured for the Glen Canyon power plant, which will be located about 470 feet downstream from the axis of the dam. It will be 665 feet long, 113 feet wide and 150 feet high. Its initial electrical output will be 900,000 kilowatts, but provision has been made for ultimate installation of eight 112,500-kilowatt generating units. The capacity of each turbine is 155,500-horsepower and the rated head is 450 feet. Water will be conveyed to each generating unit through a 15-foot steel penstock embedded in the dam. Two spillways above the dam will carry off flood waters, and four outlets

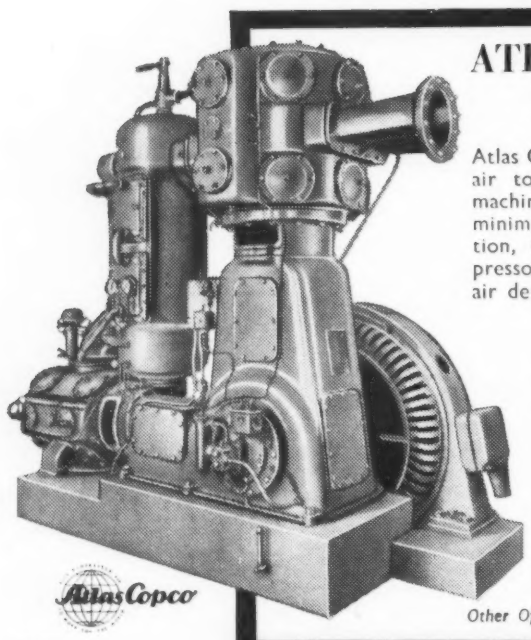
below the dam will release water downstream when the power plant is not operating.

The water-storage reservoir that will be formed by Glen Canyon Dam will cover an area of 256 square miles. The capacity of the lake, which will be one of the largest ever made by man, will be the total average flow of the Colorado River for two years. The reservoir will be a recreation area and preserve for fish and wildlife, from which water will be released as needed for irrigation in the Upper Colorado River Basin and for operation of the Glen Canyon power plant.

When completed, the Glen Canyon project will reclaim a large, valuable area. A total of 132,360 acres of land for farms will be irrigated, and 234,000 acres already under cultivation will receive supplemental water. The result will be greater agricultural production, mainly of specialty crops, row crops and food products not in surplus. Access to power and water also will stimulate the development of the Basin's natural resources. Oil, natural gas and more than 200 different minerals are present in the area, including uranium, copper, lead, zinc, phosphates, gold, silver, gilsonite, gypsum, tungsten, molybdenum and vanadium.

The Glen Canyon project, to be completed in 1964, will unlock this "treasure chest" of natural resources, enabling the Upper Colorado River Basin to look forward to a prosperous future. New towns and industries will be established as many thousands of people are drawn to the area by employment opportunities.

The increased population will create a new market for commodities and manufactured goods produced in other parts of the country. The new Glen Canyon bridge, which is linked to highways leading to all states of the union, will permit marketing of the river basin's agricultural and industrial output and a flow of materials into the area. Eventually, the Glen Canyon project, which is being financed by the United States Government, will pay for itself and will benefit greatly the four states that it will serve.



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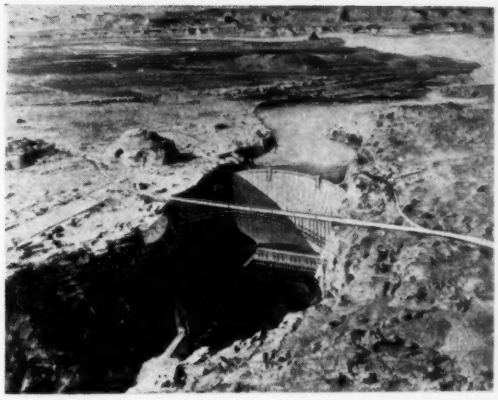
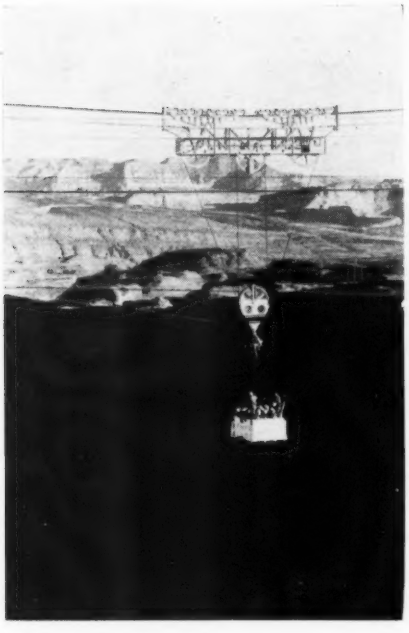
GLEN CANYON

In Glen Canyon, a deep gorge of the Colorado River in northwest Arizona, the United States Government is building the nation's second largest dam for production of electric power and storage of water for irrigation. The dam is the major structure in a reclamation program designed to benefit the entire Upper Colorado River Basin, a 4,000,000-acre desert plateau in the states of Wyoming, Utah, Colorado and New Mexico. The area is rich in minerals and suitable for farming. A 256-square-mile lake formed by the dam will irrigate thousands of acres, the power plant will supply 900,000 kilowatts of power, and a new bridge across Glen Canyon will connect with transcontinental highways.



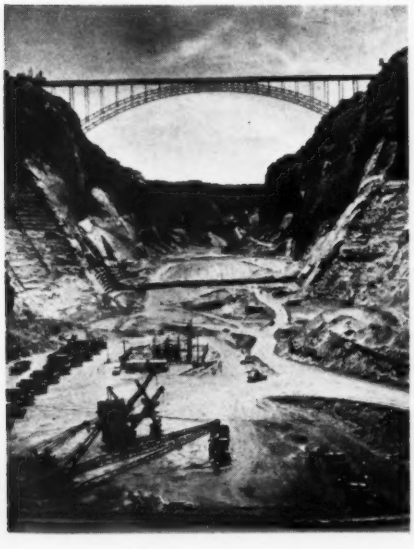
An artist's view of the project after completion.



"Box" of workmen being transported into the 700 ft deep gorge by aerial cableway. Everything necessary for construction is lowered in this manner into the canyon.

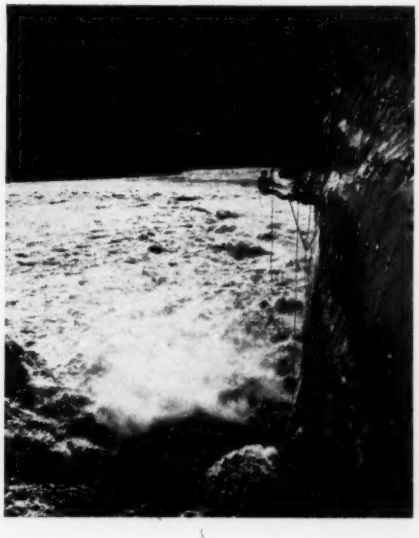
Reviewers use a transit an a walkie-talkie to plot the area.

World's highest steel arch span. Damsite at its early stage.

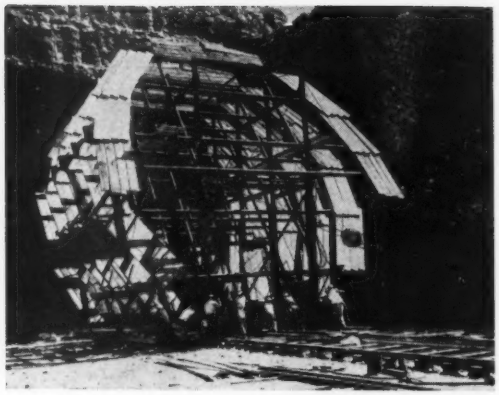


Last steel segment being placed in the Glen Canyon Bridge.

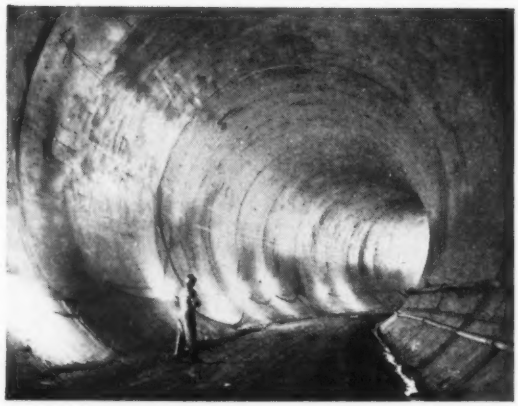
Two high-scalers are drilling holes in one wall to remove weather and insecure rock and place anchor rods.



High-scalers prepare an area for the concrete foundations or skewbacks to secure the steel arch bridge.



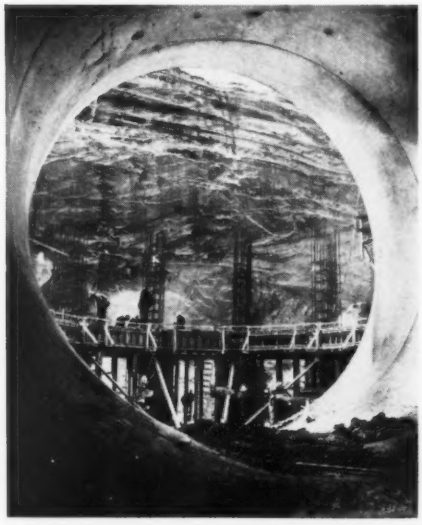
Men pushing a big gantry over rails into one of the spillways. The curving spillway is 10,000 ft long and more than 40 ft in diameter.



The concrete lining to the Dam spillway.

A dynamite blast deep in Canyon. Material excavated for foundation — 2,500,000 cu. yds.

The mouth of one diversion tunnel. Men are seen building structure to collect waste materials as they float down the river.



Shovels, trucks and men lowered by cable into the Canyon are moving rock.

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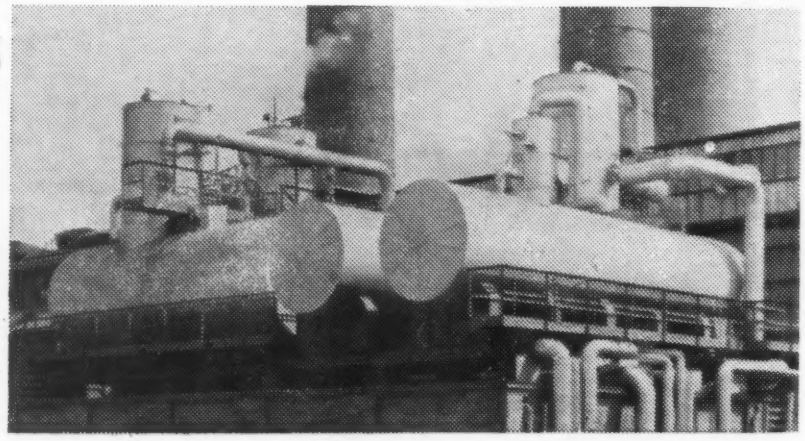

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M. V. Rao
Reader in Civil Engineering
Engineering College, Jabalpur

Trends in Hydraulic and Structural Design of Aprons of Barrages on Permeable Soil-Foundations

HYDRAULIC STRUCTURES LIKE BARRAGES, WEIRS, locks and low-head hydro-power stations are most often built on previous alluvial soil foundations. Even though the subject of this paper applies equally to the design of various hydraulic structures on permeable soil-foundations, attention is confined only to the problem of design of barrages on permeable soil foundations.

The fixed part of the barrage can be divided into (i) Super-structure, and (ii) the sub-structure. The super-structure comprises of the piers, abutments, arches, etc. The sub-structure consists of a continuous masonry or concrete apron which extends beneath the structure and cut-offs or sheet-piles placed under the apron in order to render it more effective. In many an instance, it is the sub-structure that is complicated to design and construct.

The design of a hydraulic structure consists of two phases.

(a) the Hydraulic design, and
(b) the Structural design.

The former deals with the evaluation of the hydraulic forces acting on the structure and the determination of the configuration of the structure for the best economy and functional efficiency. The structural design consists of dimensioning the various parts of the structure to enable it to resist safely all the forces acting on it. As these two aspects of the design of the barrage as a whole cannot be treated in this short paper, and as most of the modern developments in the design of the barrage, concern to its sub-structure only, (its super-structure can be designed by the accepted norms of Structural analysis and Design) consideration is given in this paper only to the hydraulic and structural analysis of the apron of a barrage on previous soil-foundation.

HYDRAULIC DESIGN

The problems involved in the hydraulic design of the barrage on permeable foundation can be explained under the following classification.

(i) Sub-soil Flow, and
(ii) the surface-flow.

The effect of the sub-soil flow is to be considered in two aspects.

(a) the residual pressure of the percolating water acting on the bottom of the apron.
(b) the exit-gradient and hence the stability of the structure against under-mining.

The problems arising owing to surface flow are (i) the determination of the optimum waterway and afflux, (ii) the stabilisation of the position of the hydraulic jump, (iii) evaluation of the effect of tail-erosion on the safety coefficient against piping.

Modern trends to solve some of the above two problems are reviewed below after indicating the earlier methods to solve the same.

VARIOUS SOLUTIONS TO THE PROBLEMS OF PERCOLATION OF WATER THROUGH SUB-SOILS OF HYDRAULIC STRUCTURES

(1) Creep-Line Theory :

Bligh, who is considered to be one of the pioneers in developing irrigation from the stage of art into a branch of Engineering, was of the opinion that the resistance to the motion of the percolating water in somewhat less along the line of contact of the profile of the sub-structure and the sub-soil or along the line of creep, as termed by him. According to Bligh, the hydraulic gradient is constant along the line of creep. In this method, the residual uplift pressure-head at any point along the line of creep is the produce of the ratio of the creep-length to the point measured from the down-stream end to the total creep length and the total seepage pressure-head.

Thus referring to Fig. 1, the residual uplift head at point G.

$$= h \times \left\{ \frac{LK + KH + HG}{BC + CD + DE + EF + FG + GH + HK + KL} \right\}$$

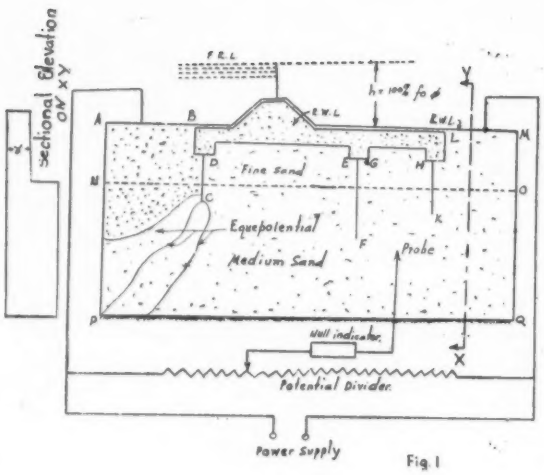

Fig. 1

Bligh believed that the apron is safe against undermining and piping, if the ratio $\frac{L}{H} = C$ is not less than a certain value, e.g. for Indian-soils C = 12 to 15.

Generally, the origin of piping may be traced to two alternative causes.

(1) Direct percolation through the granular foundation material.

(2) Percolation along the line of creep.

Bligh neglected entirely the failure due to direct percolation through soil. Besides that, no discrimination was made by him between vertical and horizontal creeps in assessing their effectiveness against undermining or piping.

Lane approached the problem by making a statistical examination of the existing structures taking into account the results of 'The potential theory of seepage flow'. He evolved 'the weighted-creep theory' which in effect may be called "Bligh's Creep theory corrected for vertical contacts".

According to Lane's 'Weighted Creep theory' the weighted creep-length (L_w) is given as,

$$L_w = \tfrac{1}{3} N + V.$$

Where,

N is the sum of all the horizontal contacts and all the sloping contacts less than 45°

V is the sum of all the vertical contacts plus the sloping contacts>45°.

To ensure safety against piping (L_w) must not be less than "C : H" where H is total seepage pressure-head, i.e. the difference of water levels on the up-stream, and the down stream, while, 'C' is an empirical coefficient depending on the nature of the soil in the foundation as shown in the following table.

Material	C safe weighted creep-ratio	C (Bligh's Value)
Very fine sand or silt	8.5	18
Fine sand	7.0	15
Coarse sand	5.0	12
Gravel and sand	3.5 to 3	9
Boulders, gravel and sand	2.5 to 3	4 to 6
Clayey soils	3.0 to 1.6	4 to 6

According to Lane, the residual uplift pressure at any point along the line of creep can be computed, by applying the relative weight age of 3 to 1 for vertical and horizontal contacts respectively.

Thus referring to Fig (1), the residual uplift head at the point G is,

$$= h \times \left\{ \frac{\frac{1}{3} GH + (LK + KH)}{\frac{1}{3} (DE + GH) + (BC + CD + EF + FG + HK + KL)} \right\}$$

While Lane's weighted creep theory is an improvement over Bligh's creep theory, it too suffers, like Bligh's theory, the limitations of an empirical method. At best, it can be used as an alternative method in testing designs to serve as a basis of comparison.

(2) **Potential Flow Theory :**

(a) *Mechanics of Seepage Flow :*

It was Darcy, a French hydraulic engineer, who first studied experimentally the mechanics of seepage flow through saturated homogeneous pervious soils and discovered a law which states that the velocity of flow through porous media is proportional to the first power of the hydraulic gradient.

Writing symbolically,

$$V = K i$$

Where 'K' is the transmission constant. Its value depends not only upon the permeability of the soil but also on the significant properties of the fluid flowing through the soil. As in most seepage problems, the kinetic energy is negligible even though variable, the energy gradient may be replaced by the gradient of the piezometric head (P/w + Y). Since the velocity in the laminar flow is also proportional to the first power of the energy gradient, it can be inferred that the flow must be laminar for Darcy's law to hold. This formula does not apply very accurately to percolation through very coarse grained soils. The analysis that follows is based on Darcy's law.

(b) *Seepage Flow as Potential Flow :*

According to Darcy's Law,

$$V = Ki = -K \frac{d(P/w = Y)}{d_s} = \frac{K \, d\phi}{d_s} \quad \ldots\ldots (1)$$

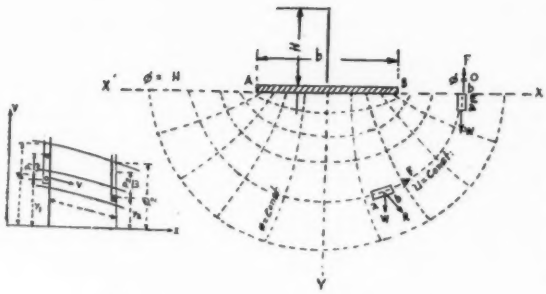

FIG. 2

FIG. 3

Where $\phi = (P/w + Y)$, d_s is the distance along the average direction of flow. (Vide fig. 2).

In terms of the three components of velocity,

V; (Vx, Vy, Vz)

$$Vx = -K \frac{\delta \phi}{\delta x}$$

$$Vy = -K \frac{\delta \phi}{\delta y} \quad \text{..... (2)}$$

$$\text{and } Vz = -K \frac{\delta \phi}{\delta z}$$

the negative sign indicates that the hydraulic potential reduces in the direction of flow.

If the flow is steady and the fluid is incompressible, from the law of conservation of matter, the net flow into and out of any elementary volume of space is zero.

This may be expressed by the equation of continuity as,

$$\frac{\delta V x}{\delta x} + \frac{\delta V y}{\delta y} + \frac{\delta V z}{\delta z} = 0 \quad \text{..... (3)}$$

Substitution of equations (2) in the continuity equation (3), shows that 'ϕ' must satisfy the Laplace equation,

$$\frac{\delta^2 \phi}{\delta x^2} + \frac{\delta^2 \phi}{\delta y^2} + \frac{\delta^2 \phi}{\delta z^2} = 0 \quad \text{..... (4)}$$

Hence the sub-soil flow is governed by Laplace equation and hence it conforms to the Potential Flow.

(c) *Sub-Soil Flow under the apron of a barrage :—*

As the variation of tne seepage velocity - component along the length of the barrage (along Z-axis) across a wide river is negligible, the sub-soil flow can be considered to be two - dimensional. All tne important characteristics of sub-soil flow are observable in one plane and can be translated to the flow in any section, under similar conditions. Hence equation (4) reduces to,

$$\frac{\delta^2 \phi}{\delta x^2} + \frac{\delta^2 \phi}{\delta y^2} = 0 \quad \text{..... (5)}$$

The form of seepage flow (Potential Flow) can be determined by integration of the differential equation of Laplace for the given boundary conditions; Conditioning the Problem.

(d) *Boundary conditions :—*

The following boundary conditions of the permeable field shown in Fig 1 are as follows:—

(a) Between A and B, the potential function ϕ (x, y) is constant and equal to (h) when the down stream river bed-level si taken as the datum.

(b) Between L and M, the function ϕ (x,y) remains constant and it equal to zero.

(c) The component of velocity perpendicular to the impermeable boundary (B C D E F G H K L) and P Q must be zero. If n is in the direction perpendicular to the impermeable boundary, $\frac{d\phi}{dn} = 0$, at the boundary.

The problem is to find the unknown function, $\phi(x, y)$ satisfying simultaneously,

(a) The boundary conditions, as stated above, and

(b) Laplace equation, i.e. $\frac{\delta^2 \phi}{\delta x^2} + \frac{\delta^2 \phi}{\delta y^2} = 0$

(e) *Application of the theory of complex variables for seepage-flow beneath a flat apron.*

It can be shown that any function of a complex variable $f(z) = f(x + iy)$ which is defined throughout a region and has a derivative throughout a region is a possible case of the fluid-flow and is a solution to the two dimensional Laplace's equation.

Let us consider the following complex function,

$$z = \frac{b}{2} \cosh \frac{\pi \omega}{H} \quad \text{..... (6)}$$

where $z = x + i y$ and

$$W = \psi + i \phi,$$

the symbols ϕ and ψ stand for the potential and stream functions respectively. Placing the expressions for z and W in the above equation,

$$(x + i y) = \frac{b}{2} \cosh \left(\frac{\pi}{H} \psi + i \frac{\pi}{H} \phi \right)$$

$$= \frac{b}{2} \cosh \frac{\pi}{H} \psi \cos \frac{\pi}{H} \phi + \frac{b}{2}$$

$$i \sinh \frac{\pi}{H} \psi \sin \frac{\pi}{H} \phi$$

Equating the real and imaginary parts, we get,

$$x = \frac{b}{2} \cosh \frac{\pi}{H} \psi \cos \frac{\pi}{H} \phi \quad (7)$$

$$y = \frac{b}{2} \sinh \frac{\pi}{H} \psi \sin \frac{\pi}{H} \quad (8)$$

from the above equations (7 & 8) we obtain,

$$\frac{x^2}{\left(\frac{b}{2}\cosh\frac{\pi}{H}\psi\right)^2}+\frac{y^2}{\left(\frac{b}{2}\sinh\frac{\pi}{H}\psi\right)^2}$$

$$=\cos^2\frac{\pi}{H}\phi+\sin^2\frac{\pi}{H}\phi=1 \qquad (9)$$

and

$$\frac{x^2}{\left(\frac{b}{2}\cos\frac{\pi}{H}\phi\right)^2}-\frac{y^2}{\left(\frac{b}{2}\sin\frac{\pi}{H}\phi\right)^2}$$

$$=\cosh^2\frac{\pi}{H}\psi-\sinh^2\frac{\pi}{H}\psi=1 \qquad (10)$$

By letting ψ =const. we obtain a set of confocal ellipses given by

$$\frac{x^2}{\left(\frac{b}{2}\cosh\frac{\pi}{H}\psi\right)^2}+\frac{y^2}{\left(\frac{b}{2}\sinh\frac{\pi}{H}\right)^2}=1$$

By letting ϕ =const, we obtain a set of confocal hyperbolae given by,

$$\frac{x^2}{\left(\frac{b}{2}\cos\frac{\pi}{H}\phi\right)^2}-\frac{y^2}{\left(\frac{b}{2}\sin\frac{\pi}{H}\phi\right)^2}=1$$

Now if A B in fig. (3) represents the flat apron of a hydraulic structure over which there is a difference of head (H feet), the lines ψ =const. will conveniently represent the lines of flow due to seepage. The lines ϕ =const, represent the lines of constant hydraulic potential. That this is a correct solution follows from the fact that ψ and ϕ being real and imaginary parts of

$$W=\frac{H}{\pi}\cosh^{-1}\frac{2z}{b}$$

will satisfy two-dimensional Laplace equation.

Further, the river bed Ax′ is a line of constant potential ϕ =H and B x′ is a line of constant potential ϕ =0.

To find the uplift pressures beneath the apron, we must consider the first steamline which hugs the outline of the solid-apron. As the discharge between this and the solid apron is zero, the stream function ψ is zero.

Substituting this value in equation (7)

i. e. $x=\frac{b}{2}\cosh\frac{\pi}{H}\psi\cos\frac{\pi}{H}\phi$ we have,

$$x=\frac{b}{2}\cos\frac{\pi}{H}\phi \qquad (11)$$

∴ we obtain,

$$\phi=\frac{H}{\pi}\cos^{-1}\frac{2x}{b} \qquad (12)$$

From the above result, we get

ϕ =H at x= $-b/2$

and ϕ = 0 at x = $+b/2$

This shows that the derived expression for the potential, satisfies the boundary conditions of the problem.

The uplift-pressure at any point beneath the apron is proportional to ϕ. When the effective seepase head is H, with the downstream river bed level taken as the datum, the uplift-pressure heads along the base of the apron are given by the following equation.

$$P=\phi=\frac{H}{\pi}\cos^{-1}\frac{2x}{b} \qquad (12)$$

By substituting different values for x in the above equation, we get, the corresponding values of uplift pressure heads.

The uplift pressure gradient curve derived from the potential flow theory deviates markedly from the uplift pressure gradient line as per 'the creep line theory' of Bligh.

(f) *Rational criterion for safety against piping :*

Terzaghi was the first to point out that the failure by piping does not take place as conceived by Bligh, when the average pressure gradient along the creepline exceeds a particular value. He proved experimentally that failure by piping occurs only when the pressure gradient at exit is in excess of "the floatation gradient or critical gradient".

Consider the equilibrium of an element of material "a b" along one of the streamlines (see Fig 3).

Let 'd_a' be the cross-sectional area of cylinder ab and 'd_s be its length.

Force at Face a = Pd_a = wh d_a

Force at Face b = (P + d p) d_a = W (h + dh) d_a

The resultant seepage force acting on the cylinder along the streamline is

$$= W h d_a - W (h + dh) d_a$$

$$= -W dh. d_a$$

∴ per unit volume of the cylinder O R F $= -\frac{W dh. d_a}{d_a . d_s}$

or F $= -W\frac{dh}{d_s}$

Besides this force, the element 'ab' is subjected to its sub-merged weight.

If ρ = sp. gravity of sand particles,

e = porosity of the material, then,

submerged weight of the element A B

$$= W(1-e)(\rho-1) d_a . d_s$$

which per unit volume gives,

$$W_s = W (1-e) (\rho-1)$$

At the exit end (E), the seepage Force (F) is vertically upwards. The resultant of F and W_s should be either zero or downwards for the equilibrium of

the sand particles at the exit. It is the equilibrium at the exit that should be considered as the sand at the exit of the river bed should move to cause sand at greater depths to move.

Hence for limiting equilibrium, the submerged weight of the soil should just balance the seepage force

$$F = W^s$$

$$-W\frac{dh}{d_s} = W(1-e)(\rho-1)$$

$$\therefore \left(-\frac{dh}{d_s}\right) = (1-e)(\rho-1) \qquad (13)$$

At this stage, the slightest increase in the value of F will cause the soil-particles to be lifted up and ultimately undermine the structure. The Pressure gradient at which this occurs, has been aptly called by Terzaghi as "the floatation gradient".

Floatation gradient $= (1-e)(\rho-1)$

$= (1-0.4)(2.65-1)$

$= 0.6 \times 1.65 = 0.99$

= Unity (if $e = 0.4$ and $\rho = 2.65$) (app).

Therefore the exit gradient should not exceed unity to prevent piping phenomenon to occur. Actually a factor of safety of 4 to 7 was recommended by Khosla.

In the Problem of Fig. (3), the exit gradient $\frac{dP}{dx}$ can be determined from equation (6)

$$P = \frac{H}{\pi}\cos^{-1}\left(\frac{2x}{b}\right)$$

$$\frac{dP}{dx} = \frac{2H}{b\pi}\,\frac{1}{\sqrt{\left(\frac{2x}{b}\right)^2 - 1}}$$

Hence at B, where $x = b/2$,

$$\frac{dP}{dx} = \infty$$

The exit gradient at B being ∞ undermining is bound to start at the toe of the flat apron. This result repudiates the contention of Bligh that piping will not occur at the toe of the structure, provided provision for sufficient creep length is made. The significance of this rational analysis is to make us understand the necessity of providing a down-stream cut-off below the flat apron to keep the value of the exit gradient much below the floatation gradient.

(g) *Analytical solutions applied to composite profiles of weirs and barrages :*

The following are the elementary profiles for which complete mathematical solutions are available.

(a) A horizontal apron with no piles and no depression.

(b) A horizontal apron with a pile line anywhere along it, but no depression.

(c) A horizontal apron with a depression in the subsoil but no pile line.

(d) A horizontal apron with equal pile lines at either end but no depression of the former.

(h) *Khosla's Method of Independent Variables :—*

The usual barrage and weir sections rarely conform to any one single elementary form. To apply the analytical solutions for the above elementary profiles to any practical composite profile of a barrage or a weir, Khosla evolved the method of independent variables. In this method, a composite barrage or weir-section is split up into its elementary standard forms. Each elementary form is then treated as independent of the others. The pressures at the junction points of the apron and the pile line of that particular elementary form, the bottom point of that pile line are obtained from the analytical solutions available. The readings at junction points are then corrected for,

(a) the mutual interference of piles,

(b) the apron-thickness, and

(c) the slope of the floor.

In Khosla's method, the floor and the down-stream pile line should be taken as the elementary profile for the computation of the exit gradients. For this case, the analytical solution is available.

$$\text{Exit gradient} = \frac{H}{\pi d}\,\frac{1}{\sqrt{\lambda}}$$

$$\lambda = \frac{1+\sqrt{1+\alpha^2}}{2}$$

$$\alpha = \frac{b}{d}$$ where b — total floor length

d — Depth of Down stream piling.

H — Head.

The results obtained by Khosla's Method of independent variables are found to be fully satisfactory.

To be continued

GUIDANCE FOR AUTHORS

Normally, only original manuscripts will be accepted. No manuscript is acceptable if an appreciable portion of its subject matter is readily available elsewhere in published form. The authors are requested to note carefully the following before sending their contributions;

1. The manuscript should be typewritten on good paper of uniform size (quarto or foolscap) with *generous margins and double spacing between the lines.* The pages should be numbered consecutively, and only one side should be used.

2. The original copy of the manuscript, and not a carbon copy, must be submitted. Mathematical symbols and Greek letters should be inserted in ink clearly.

3. The length of a paper will naturally depend on its subject matter but it should be as short as the nature of the subject will allow. *Brevity is the essence of a good contribution.* There should be no undue recapitulation of well-known first principles or engineering theory and practice. The length of an article is limited to 5000 words. Papers of 5000 to 3000 words will be very acceptable. Each paper must give an *abstract (not an introduction) in about 150 words,* suitable for printing at the head of the paper.

4. Manufactured products should not be referred to by a maker's name or a trade-name unless that is unavoidable.

5. The contents of a contribution should usually be arranged as follows:

* (a) Title
(b) Table of Contents
(c) Abstract
(d) Main Text
(e) Conclusions
(f) Acknowledgments
(g) References or Bibiliography

* The title of paper should indicate briefly the main subject. When writing his name beneath the title, the author should give particulars of his professional position, or occupation and indicate his rank.

6. The contribution should be accompanied with a brief note about the author's professional and educational background, etc. on a *separate* sheet and a copy of his photograph.

7. Abbreviations and symbols should conform to accepted standards. If any phrase or word, not commonly abbreviated, is abbreviated for convenience it should be explained when first used.

8. Section headings, sub-headings and paragraphs should be inserted to divide the text into its natural parts.

9. Extended mathematical proofs, digressions and detailed explanations of methods, tests etc. should be excluded; they can be added, if necessary, in the form of appendices. Long quotations should be avoided; normally, a reference to the original publication in the text should suffice.

10. References must be complete and accurate. The details required are:—

For books and pamphlets: author(s), title, publisher, place of publication, date of edition and page number(s) if relevant.

For Journals: author(s), title of article or paper, *unabbreviated* title of the Journal, date of issue, volume, and page number(s).

11. Tabular matter should be kept to a minimum. All tables should be numbered consecutively in *Roman* numerals and should carry a clear heading. Each table should be *referred to by its number in the text.*

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13. The number of illustrations to each paper must normally *not exceed 10 figures*—graphs or photographs. The editor, however, reserves the right not to publish any of them.

14. Photographs must show some unusual or unique features which cannot be explained concisely in words or by means of a line drawing.

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17. Coloured illustrations should be avoided. Any distinction necessary in sectional drawings can be indicated by different kinds of cross-hatching, and in circuit diagrams by the use of different kinds of broken line.

18. Illustrations must not be drawn in or pasted on the text of the manuscript. The (both drawings and photographs) should be numbered consecutively throughout with *Arabic* numerals and carry a brief description on the back in pencil. Each should have a brief caption, and be referred to in the text. Where confusion may arise, pencil marking on the back is essential.

19. Reading matter on an illustration should be kept to the minimum. Reference letters may be placed on the illustration and explained with the caption notes or in the text. The captions and caption notes should preferably be collected and listed on a separate typewritten sheet. Legends and lettering, if included on illustrations, should be in large type sufficiently bold to remain legible after reduction.

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The authors will be normally supplied with 20 copies of off-prints free of charge for their article. If more off-prints are needed, they should intimate their requirements at the time of sending their contribution.

P. K. Menon

Problem of Power Development

POWER DEVELOPMENT IN INDIA IS A CONCURRENT responsibility. States generally initiate all the preliminary investigations and project planning. But it is the Centre with its control over finances and foreign exchange that has the last word. Even in matters technical Centre exercises its scrutinizing authority. The total capacity that all the States together may install in any given 5-Year Plan period is again decided by the Centre. Thus it is the Centre which decides how much, when and where the power facilities are to be developed and it is the Centre again which provides the funds. But it is the States or their Electricity Boards which plan, execute and own these facilities. The sole exception is the DVC.

This mix-up or overlapping of responsibilities is at the root of our power development problems. A project, which should normally take about 4 years from the planning to commissioning stage, nowadays takes almost double that time. Procedural delays almost alone accounts for this excess of time. This delay and the resulting financial and other losses can only be eliminated through assumption of total and unshared responsibility for power generation and transmission by one authority for the whole country. That authority can only be the Centre.

Power development is but a forerunner of economic development: industrial, agricultural, transport, etc. But power development under present conditions takes about 8 years from project investigation to power delivery. Under our Plans we double the investment for economic development every five years. In the same period we also provide for doubling the installed capacity for power generation. But where we go wrong is in the timing of these investments. We plan to develop in the Third Plan period power facilities required for the Third Plan economic development, whereas, on consideration of priorities, these power facilities should have been developed during the Second Five-Year Plan period. So, the lack of correct appreciation of priorities in economic planning has been one of the major causes of our present and recurring power shortages.

The power problem in the Eastern Zone is unique only in that there is a scapegoat in the DVC for all drawbacks or short-sightedness of the Centre and the States. With all other States the blame for shedding of loads at particular periods is directly shared between the Centre and the States. It may be lack of foreign exchange, shortage of technical personnel, lack of proper sites or power resources, and, somewhere, it is the unenviable quarrel between States regarding appropriating resources. Whatever the cause or causes be for the want of power where it is needed most, one thing is quite clear: we are in a great mess organisationally and in much greater confusion over priorities in planning and developing power resources.

The Centre does the overall planning of economic development of the country. It could easily estimate its resources for such development at least five years ahead. It could, therefore, also foresee the power requirements during this period: how much, when and where. It has under it the best technical organisation in the country for undertaking investigation, planning, execution and operation of power facilities: CW & PC. It has the funds. It may, if need be, allow the CW & PC to set up zonal authorities to execute these functions. Perhaps in that case DVC may be expanded to cover the Eastern Zone. The State Electricity Boards in such an organisational set-up should function only as power distributing and load development agencies. They may undertake other activities related to the execution of these two functions.

In the organisational set-up visualised here the responsibilities of the Centre and the States are separate and exclusive. There is no overlapping. There would thus be no cause for unnecessary procedural delays and the resultant financial and other losses. More than that, this set-up helps eliminate altogether the duplication of employment of technical personnel which everybody always claims is in short supply. To be precise, technical personnel may not then have to be employed, as at present, by so many agencies to do the same job over and over.

Location of needed resources (fuel and water) as well as technological development compel us to plan in terms of power systems embracing more than one State. Water and fuel resources within a State is either more or less than the power requirements of the

State. Where it is more and attractive on economic considerations, it is in the overall national interest that power development there is given priority over the neighbouring States' economic resources which may not be so advantageously placed, even when the latter States have bigger load development. Such a development of power facilities is ultimately in the best economic interest of both the power producing and consuming States.

We are at the moment adopting sets of a maximum capacity of 125 MW whereas it has been established that sets of 200 or more megawatt capacity achieve the maximum economy. Even a 125 MW set, to be economic, has to be installed in a power system carrying a load at least 10 times the unit capacity. So if we are to instal sets that are modern, much larger and most economic, the power systems in which we install them have to carry loads that are, on present estimates, far beyond what any single State could develop even at the end of another decade. In adopting, therefore, a regional multi-State grid system the country not only could install the most efficient and economic unit but also could save on investment for standby and spinning reserve.

Standardization of equipment is another advantage that could accrue from a regional multi-State grid system; for such a system would bring down the number of purchasing agencies to the minimum, say 4 to 5, for the whole country. Consequently, there could be saving in both investment and time in installing power facilities.

Regional grid offers maximum load adjustment facilities. Since such a grid embraces concentrated industrial and urban load centres within a much larger area of agricultural and rural industrial load, the latter load being easily adaptable to system load conditions, the system as a whole could achieve and maintain a very high load factor. This particular advantage of high load factor alone is of very great importance in promoting rural electrification.

To sum up, our power problems are of our own making. Everywhere it is the unseemly over emphasis on State's autonomy but somewhere it is also the misestimation of priorities in development planning. Whichever is the root cause of the problem, it is high time we took them into serious consideration and evolved an abiding and workable solution.

(Continued from page 18)

ESTABLISHMENT OF SUPER-GRIDS AND.....

bility of generating and supplying power in bulk in different regions formed with the consent of the State authorities and State Electricity Boards. These Boards should be self-financing authorities conducting their business on normal commercial lines under a central supervision. The responsibility of distribution of power will remain vested in the State Electricity Boards.

There should be a Committee of the representatives of the Zonal Boards which will facilitate the interchange of power between different zones through inter-Zonal connections.

It will need sustained effort on the part of a number of power engineers to set out the pattern of the interconnected regional or zonal grid and to draft the constitution of the Zonal Board. It is suggested that two committees may be formed consisting of power engineers from different States and Corporations; one will work out the most convenient pattern of the zonal grids and future interconnections for putting up a programme for consideration of the State and the Central Government, and the other will draft the constitutional pattern of the Zonal Generating Board and Inter-Zonal Council.

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Development of Eastern Rivers

WE are glad to note that at last the Government of India has taken a firm decision to get along with the Farakka Barrage Project on the Ganges. This should have been taken up long ago, even as early as 1950 and in that case the Barrage with its multiple uses would have been in operation by now. We have been one of the chief and persistent campaigners for the scheme, not with a parochial outlook but with the national interest in view. It is satisfying to find that those in authority have now come round to our view albeit belatedly. Let us hope no effort will now be spared to execute the scheme on an urgent schedule.

The Pakistan Government has recently objected to the scheme. But if it takes a reasonable view of its own requirements of water from this river it will find that this scheme will not harm it; on the contrary, it may prove to be helpful to Pakistan in times of emergency.

There has now arisen—as it was bound to arise at one time or the other—the problem of co-ordinating and integrating water resource development in the entire Eastern Zone covering the river systems flowing through Assam, East Pakistan, West Bengal, Sikkim and Bhutan. It is thus a good sign that Indian and Pakistani engineers are collecting and exchanging hydrological and other data about the rivers of this area. This is a humble but essential beginning. At a later stage it may be helpful to evolve and study various projects on this zonal basis. But all this would depend upon the existence of goodwill and spirit of co-operation between all the various States concerned. At this stage we would suggest that before the States go very much farther in drawing up their respective plans for flood control, irrigation and power it may be helpful to draw up a Master Plan for this entire zone in which the statewise plans could be fitted in. That is just common sense. We now leave it to the authorities to give serious thought to the matter.

LESSONS FROM POWER SHORTAGE

In recent months there has been shortage of electric power almost in all the States in the country, accompanied by breakdown of plants or delay in the commissioning of new plants that were overdue. This has highlighted the power problem all over the country. It now appears that this shortage in most place is going to continue for some time. For, the demand for power is ascending steeply while the planned installation is not adequate and that even is delayed in being on the actual shelf.

As a result of this experience several obvious conclusions can be arrived at and it is urgent that these are considered by the authorities.

One of them is that regional inter-state grids should be established without delay in order that even the present installed capacities are fully utilised on the basis of fluctuations of load in different areas at different periods of the day or seasons. Elsewhere in this issue the matter has been fully explained.

Another obvious conclusion would be that generation needs to be planned also on a regional basis, putting up large stations near the site of fuel or hydro source, utilising the latest technical developments. But this can be undertaken only when the outlook is no longer restricted by the State boundary. Economic and technical considerations must supercede narrow political considerations: one cannot have it both.

The waste of extremely valuable time in putting up a plant must now be stopped. Large power stations take at least 5 years even in Western countries to put up—counted from the date of placing the order. We here are less efficient. But on top of it we waste *years* in preliminary stages before the plant can be ordered. Can't we reduce this to the barest minimum?

It was a sad mistake to have held up several power projects under the Second Plan for lack of either finances or foreign exchange. Now we must have learnt the bitter lesson that power must be on the shelf far ahead of other industries. At least we should have. Now the stage has been reached when far-sighted planning and active execution are more important than the controversy between the public and the private sectors. Let us have the results. Let not the authorities waste time in hair-splitting ideological issues when the Third Plan itself is threatened by power shortage.

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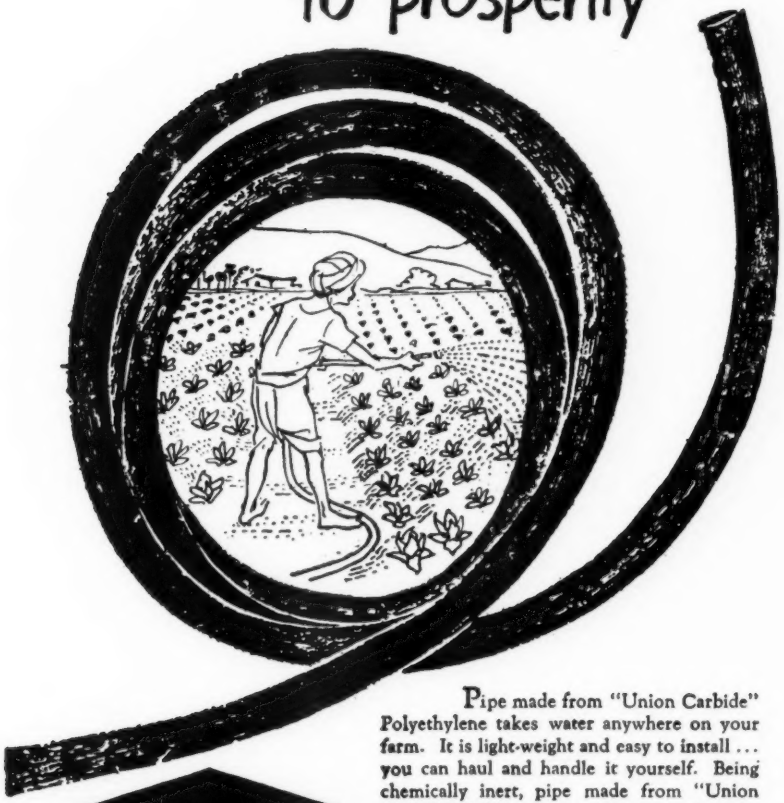

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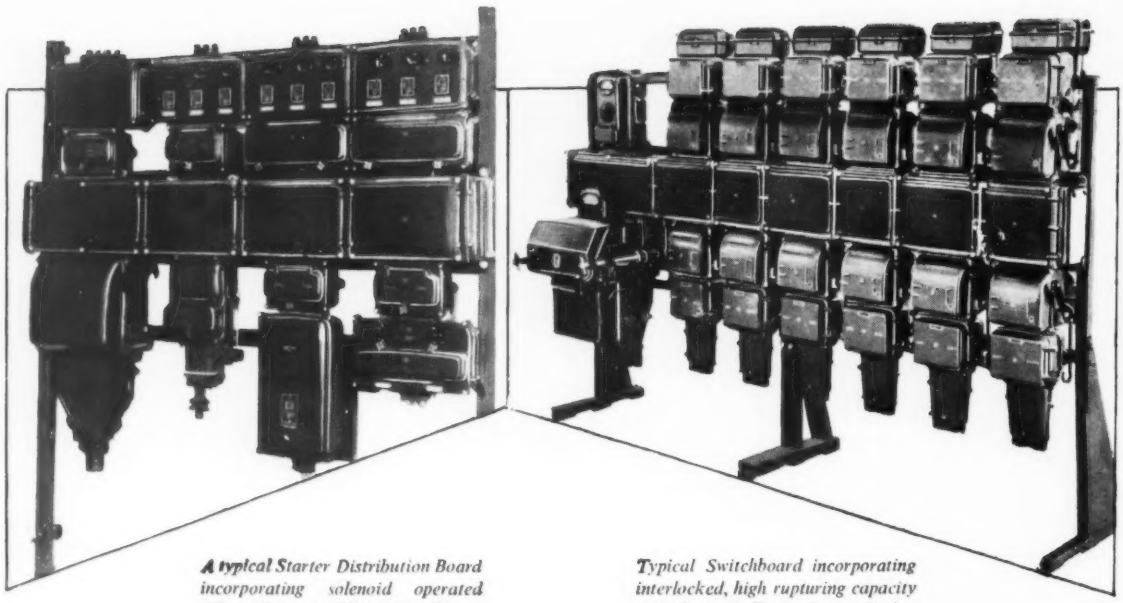

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